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Contents for October 15, 1916

The Steel Market Takes New Life

A new chapter in the history of the steel market has been commenced. Early this year the common view was one of doubt whether full activity at the steel mills would continue throughout the year. The rapid advances in steel prices that occurred in January, February and March, equal to those that had already occurred during the calendar year 1915, seemed to suggest not only a merry life but a short one for the "steel boom." When the buying of steel decreased steadily during the next three months the view seemed to be confirmed that there could be no long period of full mill activity without a general readjustment in prices. Once the heaviest buying had ceased and prices had practically stopped advancing, the testimony of all precedents was that the market movement was over and a fresh start would have to be made.

Now the unprecedented is occurring. The railroads, which had withdrawn completely from the market, have entered it again, although confronted by higher prices than when they withdrew. Freight car buying since Sept. 1 has been at a rate that by the precedents must be considered a good one. Rails are being bought for delivery early in 1918, the earliest delivery obtainable. Other consumers of steel, such as agricultural implement makers, find that the public will buy much more of their goods, at the high prices they must ask, than they had expected. The new information is that the public will pay more for steel than was judged according to the precedents. That is simply because all conditions have changed.

The steel mills are as much crowded with work as they were four months or six months ago and steel prices are advancing much more clearly and sharply than at any time since last March. It can be seen that it is a new chapter in the history of the steel market. How long the chapter will be time must develop.

Wilmington Decision in Miami Flotation Suit

The voluminous record of flotation litigation was enriched on Sept. 29 when Hon. Edward G. Bradford, judge of the U. S. District Court for the District of Delaware, filed his opinion in the case of Minerals Separation, Ltd. vs. Miami Copper Co. Miami Copper was sued for infringement of three patents 835,120; 962,678; 1,099,699. The essential basis of Judge Bradford's decision is that the reduction of oil to less than 1 per cent is patentable. He sustains and declares infringement of claims 1 and 12 of the patent 835,120 and all claims of 962,678. He declares invalid claim 9 of patent 835,120 and all claims of 1,099,699. While technically a "mixed" decision, it is decidedly in favor of Minerals

Separation. In view of the wide interest in the suit, we publish Judge Bradford's decision practically in full elsewhere in this issue.

Judge Bradford's decision is in line with the former decision of the lower Court of Butte, Mont., in the other flotation suit now pending—that of Minerals Separation, Ltd., vs. James M. Hyde, relating to the practice at Butte and Superior. This decision of the lower court at Butte was, however, reversed by the U. S. Circuit Court of Appeals for the ninth circuit sitting at San Francisco, in a decision handed down on May 4, 1914. In the latter decision the Court found the process "fully described in more than one of the patents of the prior art, with the single exception of the reduced quantity of oil." On the latter score the Court held that to make such a claim valid would be "to take from others the right to use oil economically," and that "to sustain the appellee's (Minerals Separation) patent would be to give the owners thereof a monopoly of that which others had discovered." Quoting from another decision the Court then said: "A change in form, proportions or degree, doing substantially the same thing in the same way by substantially the same means, with better results, is not such invention as will sustain a patent."

Thus we have now two decisions, diametrically opposite with respect to the main point (the patentability of less than 1 per cent of oil), one from the District Court of Delaware, the other from the Circuit Court of Appeals for the ninth circuit. The latter decision is now awaiting hearing before the United States Supreme Court. It may be expected that the Miami case will be taken up at the same time by the Supreme Court. As far as we know, there is nothing that would make such procedure impossible, while there is a great deal that would make such procedure highly desirable. It is sincerely to be hoped that it be done, since for the future development of flotation in this country nothing is more important than a speedy final decision on the legal status.

Two remarks of a general nature may be added. First, while modern engineering developments move with Overland Limited speed, the execution of patent laws moves with the speed of the stage coach of our forefathers; yet for efficiency's sake both should move in synchronism. During the time from the end of the hearings to the filing of Judge Bradford's opinion, not only has the experimentation with and the actual application of the process assumed tremendous proportions, but there has also been published in technical literature the fullest discussion, largely from the laboratories of our technical schools, of the underlying principles of flotation. In none of these papers, so far as we have observed, has the relative effectiveness of small as compared with larger quantities of oil been brought out. Have all the experimenters and theorists overlooked this point which now appears all-important in law?

Secondly, different people may agree in very different degree with Judge Bradford's very liberal interpretation of patent law in the text of his Miami opinion. Yet one remark in the opinion will appear to everyone to represent an ideal goal to strive at. In the discussion of the second patent in suit, the judge finds novelty and patentability in the invention, but adds a note which we commend to the consideration of more than one million patentees in this country: "Even were the grounds on which the validity of the patent can be sustained less clear, it should have the benefit of *the presumption of validity, arising from the grant of letters.*"

If added evidence were needed to show the frightful weakness of our patent system, the whole litigation on flotation should have colossal weight. Would that we could rely with greater certainty on "the presumption of validity arising from the grant of letters."

Coal Reserves and Iron Production

It is well recognized that not the least of the material things for which the present European war is being waged is the possession of very important coal and iron ore deposits near the boundary line between France and Germany. The industrial development of nations has been regulated in very considerable degree by their command of iron and coal. As long ago as in 1866 the English government appointed a Royal Coal Commission to consider the coal reserves of the British Isles, for it was already recognized that the command of coal was a very important factor. In the future history of nations the ability to develop mechanical energy will be an important factor. It may be of interest to show the distribution of the world's coal reserves. We convert into percentages the tonnages given in "The Coal Resources of the World," published in 1913 by Morang & Company, Limited, Toronto, the total tonnage stated being about 74×10^{11}:

	Per Cent
Oceania	2
Asia	17
Africa	1
America	69
Europe	11
The World	100

The distribution of pig iron production is quite different. The present capacity is approximately 44½ per cent for the United States, 1½ per cent for Canada, 53½ per cent for Europe, and ½ per cent for the rest of the world, chiefly India, China and Japan.

In the earliest days of iron making, in the United States as well, still earlier in other parts of the world, iron was made where the ore was found, because there was wood everywhere. When mineral fuel came to be used the blast furnace was subject to two attractive forces instead of one. In some happy instances, as in the case of the Birmingham district in Alabama the coal, ore and limestone are all close together. Where a haul is necessary it is almost invariably of the ore rather than of the coal. While the manufacture of pig iron requires less weight of coal than of ore, the conversion of pig iron into useful articles requires much coal in addition.

At the present rate of coal production the known reserves would last the world about 6000 years but if the world's consumption were as great per capita as that

of the United States only 900 years would be required for exhaustion. The people of the United States have been progressing much more rapidly in an industrial way than the people of the world as a whole, this being a result, or a cause, of our large coal production.

It is quite inconceivable, of course, that the world should continue to use coal for the production of energy until the known supplies, let alone others that will doubtless be discovered, even the Antarctic regions presenting possibilities, are exhausted. We have made an infinitesimal beginning at utilizing the solar energy by harnessing some of the water power, we have wave motors, at least for exhibition purposes, and we have unlocked the atom to the extent of using some of its power for medicinal purposes. Can it be long, relative to the possible life of the coal deposits, until we secure more of the energy we need from the atom or from the sun?

Meanwhile, without knowing our precise objective, we make industrial progress and we know that it all counts. We developed the art of making steel tubes until we can transport oil and gas hundreds of miles at a trifling expense. Lake and ocean vessels transport ore and coal at a low cost. Railroads are operated every year at a smaller expense in terms of mental and physical effort involved and fuel consumed. If in a century hence, means should be found for converting solar into electrical energy with only a "reasonable" loss the mechanical arts will no doubt be able to supply means for transporting the energy from the equatorial regions as far north as may be required at a much lower cost than is now involved in producing energy from coal. If that transformation has meanwhile been greatly cheapened the day of transporting solar energy will simply be postponed.

What is really important is the facilities we have at hand at present for industrial progress, for that progress will bring us to the other things. It is important for the United States that the past few years have shown that the future of the country's iron industry does not rest entirely upon the Appalachian and Lake Superior iron ore deposits. Captains of industry have proved that South America and Sweden can be drawn upon for iron ore and a very large iron industry can be built up along the Atlantic seaboard. Fuel economies and cheapened railroad transportation make the absence of coal deposits near the seaboard of less and less consequence each year, and thus rapid industrial progress is assured if men do their part.

An Untouched Asset

At the industrial conference of the late meeting of the American Chemical Society, presided over by Dr. Grosvenor, a resolution was passed urging upon the government, in effect, a census of skilled labor needed and a census of skilled labor at hand.

Whether this is possible without a general police registration of all the inhabitants we do not pretend to say. The fact that there are just so many harness-makers and so many soap-boilers in the State of New York, against so many in Illinois, would not help. What is needed is to borrow a convention from the past and add a man's trade to his name, so that he may be classified according to this, as well as according to the letters of his patronymic. But that is not all. There is needed a large measure of invention in accountancy to bring out the information where the men of special training are. If this were accomplished so that industry might go to the swarms of common laborers and select the very men it needs so badly, and offer them the better positions and wages warranted by their training, there would be great relief all around.

The men are here by the thousand. The system of apprenticeship exists in many lands, and many an illiterate immigrant is a journeyman, if not a master at his trade. He may be working in a gang of contractors' hands on the new sewer, or on canal construction, or in the lowest order of mill work, paying tribute to the padrone or whatever the labor broker may be called in his native tongue, when he could, if put at a bench, turn out work to be proud of. The reason why we do not know where to find him is our fault, not his. We regard him as one of a bunch, and let it go at that. The poor devil has only a number, and he is lucky to have it. It is enough for us, and it is all that he can get. Since English, Irish and German immigration has ceased we have not cared very much for those Dagos and Polaks and Slavs and Greeks that have come along the plank at Ellis Island. They look foreign, act foreign, and there isn't any kind of pidgin English they can understand. Every one of them has a history, and many of them have trades, but we have claimed that we were too busy to bother about them and find out.

Now "too busy" is nearly always the lazy man's excuse. We know of a thousand acres of prime wheat land lying fallow, with wheat climbing up towards $2 a bushel, because the yahoos that hang around the country stores "aint got no time" to cultivate it. They can all speak English well enough to understand, but they can't work. These immigrants expect to work, can and do work, but because they cannot explain what they can do best they are sent off with the gang to do their least.

There are all kinds of trades, and machinery has added some, while it has killed others. But many kinds of trade at one bench fit a man for work at another. A watchmaker, for instance, is a handy man in many different industries. A good man in a bicycle repair shop is a good man in many other places.

Generally speaking, the job that is easiest to learn is the weariest to endure, and it pays the least in the end. The man who is prepared to do any kind of work is usually the one who is bankrupt in talent or in training. On the other hand, all over the country, in mines, in gangs, wherever two legs, two arms and a strong back are needed in each unit, men are working for the minimum wage, who might be earning double and treble, to their own delight and that of their employers—if it were only known where to find them. They have learned trades which are not easy to learn—but they cannot tell about it. If industry could get into communication with the men trained according to its needs, but now at hard labor in gangs, it could increase production in a surprising measure.

Readers' Views and Comments

Water Powers of the State of Washington

To the Editor of Metallurgical & Chemical Engineering

SIR:—From recent letters in your journal the casual reader might get the impression that California is the only place on the Pacific Coast where low-cost electric power is obtainable.

According to recent government statistics, the minimum potential power obtainable within the State of Washington is 4,932,000 hp., Oregon 3,148,000 hp. and in California 3,424,000 hp., a total of 11,504,000 hp., or nearly 43 per cent of the total potential power in the United States, which is available in the three coast states. It is true that California has a larger proportion of her available power developed than is the case in either Washington or Oregon.

The Puget Sound Traction, Light & Power Company, operating in the Puget Sound district of the State of Washington, now has installed in its various plants generators with a rated capacity in excess of 105,000 hp., and they are supplying a surprisingly large number of diversified interests with power. A rate to continuous users of large blocks of power of approximately $18 per horsepower-year is obtainable. Three electric furnaces are now being served and we are negotiating with two more. The rate to furnaces is ½ cent per kilowatt-hour. A better realization of the rates may be had when it is known that we are now serving seven coal mines, which mines were formerly using steam. In addition, we are supplying eight lumber and sawmills in this territory with electric current. We also have one tin smelter, two antimony smelters, and a copper smelter using from 40 to 5500 hp. There are two paper mills, twelve shipbuilding concerns, six flour mills, three cement plants, in addition to one large steel works and several smaller iron and steel plants. In addition to the various manufacturing loads carried by us, we supply the current for operating about 500 miles of urban and interurban electric railways.

Our present installed capacity can be practically doubled by the installation of additional machinery at one of our power plants, which would give us a rated capacity of approximately 200,000 hp. In addition, we have undeveloped sites at which from 85,000 to 200,000 hp. can be secured, depending upon the manner in which the development is made.

There are numerous other possible waterpower developments within easy transmission distance of Seattle. There is no other place in the United States where waterpower can be so easily obtained as in this section. Locations for manufacturing plants on tide water or transcontinental railways are numerous.

While we have no electrochemical plants, it is believed that the time is most opportune for them to locate here.

Another feature of striking importance is the fact that our ocean business has increased to such an extent that the value of our imports and exports is second only to that of New York City. This business for the eight months of this year has been in excess of $1,000,000 per day.

We have direct steamship lines to Russia, and being the closest United States port to that country, it is believed that this in itself should warrant the establishment of large concerns in this territory.

Our climate so far as working conditions are concerned is superior to that of any other part of the United States. It is possible to work outside 365 days in the year, and the efficiency of labor here is from 15 to 20 per cent greater than in any other part of the country.

Our export business is greatly in excess of that of any other port on the Pacific Coast and is increasing very rapidly. Two of our shipbuildings plants alone have contracts for vessels totaling more than $25,000,000, in addition to many other steel and wooden vessels under construction by the smaller shipyards.

When all these facts are realized, I believe it can readily be seen that we offer as much in the way of inducements for new manufacturing enterprises as any other portion of the country. With the numerous ores obtainable from Alaska and from the mountains in this vicinity, there should be in the near future many electrometallurgical and electrochemical plants that could be profitably operated here.

Seattle, Wash. W. E. HERRING.

Coming Meetings and Events

American Iron and Steel Institute, Planters' Hotel, St. Louis, Oct. 27-28.

Joint meeting of N. Y. Section American Electrochemical Society and Illuminating Engineering Society, Engineering Societies Building, New York, Nov. 9.

American Mining Congress, Hotel LaSalle, Chicago, Nov. 13-18.

American Institute of Chemical Engineers, New York, Jan. 10-13, 1917.

St. Louis Meeting of American Iron and Steel Institute

The eleventh general meeting of the American Iron and Steel Institute will be held at the Planter's Hotel, St. Louis, Friday and Saturday, Oct. 27 and 28. Friday will be devoted to the reading and discussion of papers, and the banquet will be held Friday evening at the Missouri Athletic Association. On Saturday trips will be made around the city.

National Research Council

Arrangements have just been completed in New York whereby the resources of The Engineering Foundation, under the auspices of the four principal national engineering societies, are placed at the disposal of the National Research Council, which was appointed by the National Academy of Sciences at the request of President Wilson. The object of the council is to co-ordinate the scientific research work of the country in order to secure efficiency in the solution of the problems of war and peace. The council was without funds until The Engineering Foundation, established to further scientific and engineering research, offered to place its resources at the council's disposal, including the services of its secretary, Dr. Cary T. Hutchinson, to act as secretary of the council. The offer was accepted and plans for immediate activities are being made.

Chemistry is represented on the Research Council by Prof. Theodore W. Richards of Harvard, Prof. M. T. Bogert of Columbia, Dr. A. A. Noyes of Massachusetts Institute, and Dr. L. H. Baekeland. Physics is represented by Prof. R. A. Millikan and Dr. A. A. Michelson of the University of Chicago and Prof. M. I. Pupin of Columbia University.

There is also a strong representation from the great engineering societies. Clemens Herschel, president of the American Society of Civil Engineers; John J. Carty, chief engineer of the American Telephone & Telegraph Company; Gano Dunn, president of the J. G. White Engineering Corporation; C. E. Skinner, director of the research laboratory of the Westinghouse Company, and Dr. W. R. Whitney, director of the research laboratory of the General Electric Company, are among those who will represent the engineering side of the council's work.

The important military aspects will be presented to the council by Major-General William Crozier, chief of ordnance of the U. S. Army, by Lieutenant-Colonel George O. Squier, chief of aviation of the U. S. Army, and Chief Constructor David W. Taylor, U. S. Navy. Other branches of the government are represented by Dr. S. W. Stratton, director of the National Bureau of Standards, Van H. Manning, director of the Bureau of Mines, and Prof. Charles F. Marvin, chief of the United States Weather Bureau.

Open Fall Conference of Efficiency Society

"After the war, what?" An open conference on the problems confronting this country, both employers and employees alike, will be held in New York City on Nov. 16, 17 and 18, under the auspices of the Efficiency Society. At this conference leading representatives of financial, labor, manufacturing and marketing interests will give their conception of what will be the most important phases of our problem and what should be done to meet them by each element in our business life so that the activities of each may be so adjusted as to protect the welfare of all.

While the conference is brought about by the Efficiency Society, it is an open conference in spirit as well as name. All who are interested are cordially invited to attend. We expect that your own desire to learn and to help will insure an acceptance of the invitation.

The program of the first session on Thursday afternoon, Nov. 15, is to be "present foreign conditions and their prophecy." It is planned to present existing conditions abroad in such a way as to give a concise and vivid mental picture of the probable attitude of the principal countries as it may affect our industrial and commercial progress: Russia, Germany, England, France, Latin America, the Far East.

In the second session, on Thursday evening, Nov. 16, an analysis will be given of the present industrial and commercial situation in the United States as a basis for the third and fourth session. The topics to be discussed are finance, marketing, manufacturing, labor.

In the third session, on Friday afternoon, Nov. 17, the survey of the future will be begun. Conditions in this country at the close of the war as the outgrowth of the present situation here and the future abroad, will be viewed from the standpoints of finance and marketing.

In the fourth session, on Friday evening, the survey of the future will be continued, viewed from the standpoints of manufacturing and labor.

In the fifth session, on Saturday morning and afternoon, Nov. 18, an attempt will be made to plan a course of action. How shall we meet the situation? What is the attitude of each group towards the problem and towards the other groups? What is the suggestion of each group for a constructive program? The groups in question are finance, government, marketing, manufacturing, labor.

The Conference Committee consists of Willis B. Richards, chairman; Miles M. Dawson, Lee Galloway, Frederic W. Keough, Harlow S. Parson, Hickman Price. Mr. M. L. Havey, 52 Broadway, New York City, is the secretary.

Second National Exposition of Chemical Industries

The official attendance figures for the second great Chemical Exposition show quite an increase over last year. The average daily attendance was about 13,000, as compared with a little over 10,000 last year. This is an increase of 30 per cent. As was expected, the last day was the biggest in the matter of attendance on account of its being Saturday. Wednesday, Thursday and Friday were also big days with large attendances, and it is probable that more chemists attended on these days than on Saturday. The total attendance was 78,000. The motion picture hall with 500 seats was always well filled, and great interest was shown in the pictures.

The managers of the exposition report that one half the space on the main and second floors has already been taken for next year, and some space on the third floor has been taken. It is the policy of the management to give each exhibitor preference first on his own space for the next exposition, and then on other space he may select.

At a meeting of the Advisory Committee, held on Saturday night of the exposition week, it was decided that if possible a South American section should be included next year. The "Southern Opportunity" section and "Paper" section will be continued.

To supplement the full report of exhibitors and exhibits, given in our last issue, it should be stated that the **General Chemical Co.**, New York City, exhibited C. P. and photographic chemicals and dye intermediates made at their Baker & Adamson works in Easton, Pa. It also showed samples of synthetic ammonia, ammonium salts and nitric acid. The remainder of the space was devoted to a sitting-room for the convenience of visiting chemists and their ladies, and the tea-room, in white and blue, conducted by the food department, where materials going to make Ryzon baking powder were exhibited.

Newport Chemical Works, Milwaukee, Wis., exhibited a group of "American made" coal tar crudes and intermediates, including alpha naphthylamin, nitro naphthalin, phenol, toluol, benzol, solvent naphtha, xylol and naphthalin. There was also an exhibit of turpentine and rosin.

Industrial Conferences at the Exposition

The industrial conferences which were held at the exposition and at the Chemists' Club, under the auspices of the American Chemical Society, attracted large attendances.

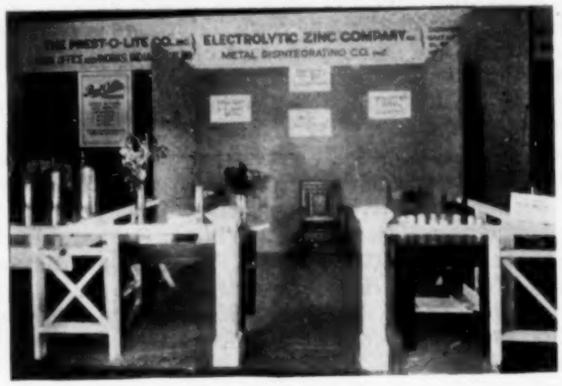
On Wednesday afternoon the conference was on "Electric Furnace Steels and Alloy Steels," with Dr. JOHN A. MATHEWS presiding. An account of this conference will be found on page 448 of this issue.

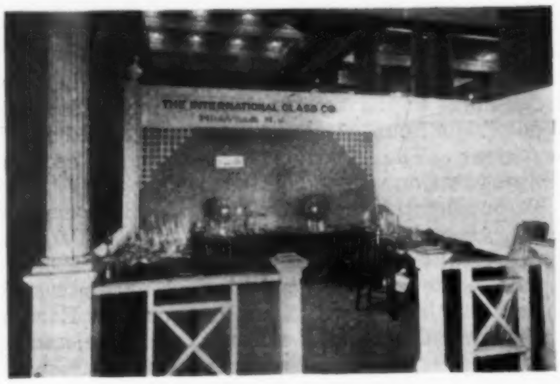
CHEMICAL GLASS AND PORCELAIN

On Thursday afternoon ARTHUR H. THOMAS presided at a conference on glass and porcelain for chemical use. Mr. Thomas said that before the war, with the exception of one large factory in the United States, which made, in addition to extensive products in other lines, a few flasks and beakers of excellent quality and reasonable price, hollow glassware for the laboratory was purchased exclusively in Europe. The American production was not, in any commercial sense, a factor in the situation.

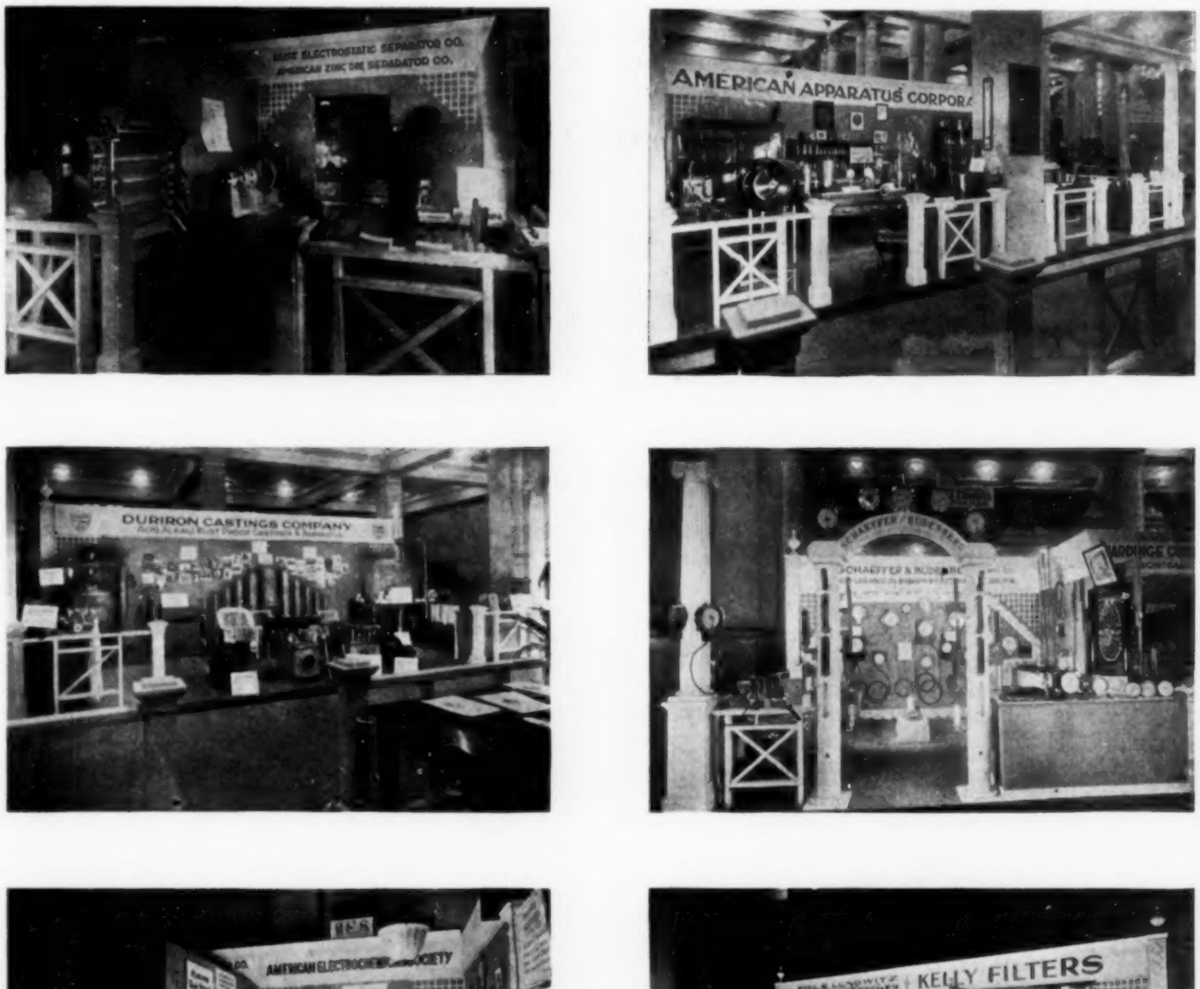
Five factories in the United States are now regularly making flasks and beakers in large quantities. The glass used by one of these is superior in several important physical characteristics to that used for similar vessels by the European factory whose flasks and beakers have been heretofore considered the best in the world.

The four other makers are using a resistance glass





Exhibits at Second National Exposition of Chemical Industries



Exhibits at Second National Exposition of Chemical Industries

much alike in physical characteristics which, while not quite equal to either the American or European product above referred to, is unquestionably superior to the glass generally used throughout Germany and Austria. There are two other American factories making flasks and beakers about which he has no definite information from actual tests.

He said the output is far from sufficient to satisfy the demand, and also advocated a duty on the glass and porcelain formerly imported in enormous quantities for routine student work. The most important consideration is an unselfish coöperation between the manufacturer, dealer and chemist.

Dr. T. B. Freas, of Columbia University, spoke on the subject of the "Decreased Supply of Glassware," and said that while our manufacturers have greatly improved the situation, they have not gone far enough. Scientifically trained men must be placed in charge of the industry. One of the greatest needs is in the microscope industry, which ought to be developed in this country to a greater extent. Our manufacturers should be protected after the war.

E. P. Sullivan, of the Corning Glass Works, said that the manufacturers of this country could compete with Germany if given sufficient time.

Prof. A. W. Smith, of the Case School of Applied Science, suggested that State laws be changed so that State schools should buy their glass from the lowest American bidder instead of simply the lowest bidder.

A. B. Davis, of Eli Lilly Company, had an interesting talk on glass blowing and showed a number of pieces made in his laboratory. He said it was possible to teach glass blowing in a short time, and that our colleges should teach it. The equipment consists simply of a blast lamp, pair of scissors and a file.

PAPER AND PULP

A conference on "Paper Pulp and By-Products" was held Friday afternoon, at which Robert B. Wolf presided.

MISCELLANEOUS CHEMICAL INDUSTRIES: CONVERTIBILITY OF PLANT

On Saturday afternoon a conference was held on the above subject, at which Dr. William M. Grosvenor presided. Dr. Grosvenor in opening the discussion said that convertibility of plant means convertibility not only to a pacific occupation, but such convertibility as will permit, if possible, the re-convertibility into munitions of war. The government is beginning to realize that we must hold together the nucleus of some of these industries that have been developed here or we will have to pay dearly for our oversight when the time should come.

The metallurgical industry has taught the chemists a great deal, in that they got together and not only told their problems, but told their solutions, and the metallurgical industry has advanced rapidly. He said chemists are too secretive. In reply to a question as to how to relieve this situation he said it was a matter of growth in which the Chemical Society was a step in the right direction. The American Institute of Chemical Engineers could perhaps do more, as its members have a greater degree of freedom, being those in charge of the industries, in one capacity or another. The Army and Navy Bureau has collected information on 16,000 plants which are manufacturing material required for military purposes.

Mr. Massie asked whether there was any bureau, either private or governmental, which classified workers so that skilled people would know where they were needed.

Mr. Jordan thought something ought to be done all over the country in this direction, and offered a resolution that the society urge upon the government to coöperate with it in making such investigations. Mr. Massie offered a similar resolution and both were adopted. Mr. Potter suggested that a committee be appointed, and a motion to this effect was passed.

American Dyestuff Manufacture

At the conference on dyestuffs held at the Chemists' Club on Wednesday afternoon, several interesting discussions took place. Dr. Chas. H. Herty presided.

Henry Wigglesworth, of the General Chemical Company, questioned whether or not conditions in this country were favorable to the establishment of a dyestuffs industry. In European countries the industry is protected by government-authorized monopolies.

Dr. Thomas H. Norton, of the Bureau of Foreign and Domestic Commerce, made public the work of a year in gathering data on the dyestuffs industry, and also a tabular summary of our importations during the years 1913-1914. As originally presented, this tabular summary showed the quantity imported by each firm, but as the presentation of these facts met with general disapproval, the information was withdrawn and the company name withheld from publication.

Dr. J. F. Schoellkopf, Jr., of the Schoellkopf Aniline & Chemical Works, outlined the present and future work of his company. He said 50 colors were carrying the burden of 1000 imported before the war. On January 1, 1916, his company was making 1,000,000 lb. of colors *per month*, whereas before the war they only had capacity for producing 3,000,000 lb. *per year*. There are now in the course of erection additions to the plant which will bring the capacity up to 30,000,000 lb. per. year, or one-half the amount which government statistics say is used in the country. After January 1, 1917, fifty colors will be made, whereas early in 1915 only fifteen were made, as no intermediates came in from Germany.

Mr. Dow stated that the omission of the specific five-cent duty from indigo, whereby the only remaining protection was 30 per cent ad valorem, put indigo makers in a very unenviable position as compared with the other dye makers, for the reason that an ad valorem duty automatically loses its protective feature at the very time it is most wanted because a lowering of the price abroad during trade war, also lowers the amount of duty and makes it relatively easy for the foreigner to compete, and put the unexperienced, new American industry out of business. Mr. Dow also explained the present status of their indigo plant at Midland, Mich., and stated that the plant would soon be producing commercially.

Dr. Mathews introduced a resolution that the American Chemical Society investigate the American dyestuff industry as a possible source of dyes for use by the Bureau of Engraving. Resolutions were also passed protesting against the exemption of indigo and alizarine in the dyestuff tariff section of the revenue bill. Indigo, alizarine, medicinals and flavors are exempt from the specific duty of 5 cents per pound imposed on aniline colors, and this feature of the bill, signed last month, has met with great disapproval.

Chemistry of Gas Lighting.

A joint meeting of the New York Section of the American Electrochemical Society and the Illuminating Engineering Society will be held on Thursday evening, Nov. 9, at the Engineering Societies Building, New York City. Papers will be presented on high pressure gas for lighting and on the new flexible mantle.

Wilmington Decision in Miami Flotation Suit

On Sept. 29, 1916, U. S. District Judge Bradford handed down a decision at Wilmington, Del., in the case of Minerals Separation, Ltd., plaintiff, vs. Miami Copper Co., defendant.

The hearings in this case were concluded on May 27, 1915, and a report of the hearings, with a review of the stand taken by both sides in the suit, was published in our Vol. XIII, page 409. Miami Copper Company is sued by Minerals Separation for infringement of three patents: 835,120; 962,678; 1,099,699.

Judge Bradford finds in his decision that the reduction of oil to less than 1 per cent is patentable. He sustains and declares infringement of claims 1 and 12 of patent 835,120 and all claims of 962,678. He declares invalid claim 9 of patent 835,120 and all claims of 1,099,699.

We herewith publish Judge Bradford's decision practically in full:

The bill in this suit was brought by the Minerals Separation, Limited, a corporation of Great Britain, against the Miami Copper Company, a corporation of Delaware, charging infringement of three United States process patents relating to ore concentration, owned by the plaintiff, namely, No. 835,120, of Nov. 6, 1906, to H. L. Sulman, H. F. Kirkpatrick-Picard and J. Ballot, No. 962,678, of June 28, 1910, to H. L. Sulman, H. H. Greenway and A. H. Higgins, and No. 1,099,699 of June 9, 1914, to H. H. Greenway, assignor to the plaintiff.

Review of Concentration and Flotation Processes

Under the processes shown in the three patents a signal advance has been made in the art of ore concentration in point of simplicity, economy, and efficiency, and in their practice large commercial success has been realized. Ore concentration in metallurgical operations is the separation of the metalliferous or metallic part of the ore from the non-metallic and worthless material, known as gangue, found associated with it in nature, in order that the valuable mineral or metallic particles may be in proper condition for the subsequent process of smelting. The ores to which the process of the patents in suit are applicable are mainly chemical compounds of metal and sulphur, copper sulphides, zinc sulphides, or lead sulphides.

Prior to the invention or rather discovery covered by the first patent in the suits concentration had assumed a number of forms differing from one another in the principle of their operation, but all of them requiring, as do the processes now practised, as an essential condition of the separation of the mineral from the gangue, the crushing or grinding of the ore into particles of such a degree of fineness as to produce useful results. The ore having been so crushed or ground was subjected to treatment to secure the desired concentration; such treatment varying, according to the particular process employed.

In what was known as water or gravity concentration the ore was mixed with water forming the ore pulp, and through shaking or agitation of the pulp by well-known devices the metallic particles, becoming separated from the particles of gangue, and having greater specific gravity than the water, sank to the bottom, while the particles of gangue, having less specific gravity than the mineral particles, although greater than that of the water, were subjected to an up-current, not strong enough to prevent the metallic particles from sinking, but strong enough to carry the particles of gangue to the surface where they would escape over the edge of the containing vessel or be otherwise disposed of. Such processes, however, were far from commercially successful, being wasteful of water, of power and of a considerable proportion of the metallic particles in the slimes which were carried by the up-current to the surface and were lost with the gangue.

Without pausing at this point to consider other processes of ore concentration disclosed in the prior art, hereinafter discussed, an important and, indeed, vital difference between water or gravity concentration under such processes as those above referred to, on the one hand, and concentration under the processes of the patents in suit, is that while in the former the metallic particles after being separated from the gangue in the ore pulp sank to the bottom, in the latter the metallic particles coated with an extremely thin film of oil, become attached to air-bubbles in the ore pulp, and the bubbles with the attached metallic particles rise to the surface, forming a mineral froth of such coherency and permanency as to afford full opportunity for its removal from the surface for further treatment of the metallic particles.

The ore pulp in the process of each and every of the three patents in suit consists of a mixture of water and crushed or pulverized mineral ore, together with one or more other ingredients. In each the agitation of the pulp coupled with the introduction of air into it develops and distributes throughout the mixture small bubbles of air which attach themselves to the metallic particles, to the exclusion of gangue, and rise with them and form a metallic air froth on the surface, readily removable therefrom, the gangue particles sinking to the bottom and being disposed of as refuse. . . . [Quotation from Patent 835,120.]

The charge of infringement of patent No. 835,120 is restricted to claims 1, 9 and 12, as follows:

"1. The herein-described process of concentrating ores which consists in mixing the powdered ore with water, adding a small proportion of an oily liquid having a preferential affinity for metalliferous matter (amounting to a fraction of one per cent of the ore), agitating the mixture until the oil-coated mineral matter forms into a froth, and separating the froth from the remainder by flotation."

"9. The process of concentrating powdered ores which consists in separating the mineral from the gangue by coating the mineral with oil in water containing a small quantity of oil, agitating the mixture to form a froth, and separating the froth."

"12. The process of concentrating powdered ore which consists in separating the minerals from gangue by coating the minerals with oil in water containing a fraction of one per cent of oil on the ore, agitating the mixture to cause the oil-coated mineral to form a froth, and separating the froth from the remainder of the mixture."

The first patent in suit is for what is known as an air flotation process, in which, owing to the use of a frothing agent in conjunction with such agitation of the ore pulp as will distribute the metallic particles of the ore throughout the mixture and produce bubbles of air and bring them in contact in the mixture with the metallic particles so distributed, the bubbles will become attached to such metallic particles, carrying them separate from the particles of gangue up through the surface of the mixture where they can readily be collected by skimming, overflow, or the use of other well known devices. In this process the frothing agent consists of an oil or other immiscible substance or material of an oily nature, and the bubbles and metallic particles become attached to each other through affinity between the bubbles and the metallic particles enhanced by the coating of the latter with an extremely thin film of oil.

The old water processes of ore concentration were in some features gravely objectionable. Under those processes it was desirable to avoid very fine grinding of the ore as being calculated to cause the fine particles containing metal constituting the slimes to escape with gangue particles and be lost, such fine metallic particles, as before stated, not sinking so readily and quickly as those which were larger. In those processes there were two things to be avoided; first, the crushing or grinding of the ore to such a degree of fineness as to lead to the loss of metallic particles through their escape with gangue particles, and secondly, too coarse a crushing or grinding whereby particles of ore containing both metal and gangue might, with the gangue preponderating, too readily be carried to the surface and lost with the other gangue particles.

The defendant admits in its brief that the air bubbles collect the metallic particles, and the oil or other modifying agent in the mixture gives permanency to the mineral froth; that the attraction of the air bubbles for the metallic sulphide particles leads to the separation of those particles from the gangue; that in the absence of oil or other modifying agent in the pulp, facilitating the formation of air or other gas bubbles, no process of ore concentration employing such bubbles is possible; that air flotation may be brought about (1) by introduction of air at the bottom of the mixture or sub-aeration; (2) by beating air into the mixture or supra-aeration; (3) by generating of gas or liberation of air in the mixture.

But there is an accentuated difference of opinion between the parties on the point of preferential affinity of oil for metallic particles as compared with gangue. The defendant in its brief stated that "in ore flotation processes the oil or other modifying agent does not have any more attraction for the metallic particles than for the gangue." This position, however, is in conflict with evidence on the part of the defendant, with the evidence on the part of the plaintiff, with the documents of the art, and with the result of the physical demonstrations made by both parties in open court. . . . [As illustrations of this statement the Court quotes from Cattermole process patent 777,273, Haynes British patent 488 of 1860, Emerson patent 348,157, Fryer Hill Publication, Oct. 30, 1889, Sulman and Picard patent 793,808, Calif.

Journ. of Techn., Nov., 1903, Kirby patent 838,626, Sulman patent 835,143.]

Patentability of Reduction of Oil to Less than One Per cent

One of the principal questions in the case is whether patentable invention was involved in the discovery that the minute proportion of 0.1 per cent of oil to the ore was sufficient for commercially successful operations in ore concentration. On this question I had some doubt during the presentation of the case. But that doubt has since been removed. Sulman, Picard and Ballot had for more than two years prior to March, 1905, been interested in conducting ore concentration under what was known as the "Cattermole process," and had been seeking to improve the same in such manner as to render it more efficient and less expensive. There was a number of patents relating to this process, using the term in a general sense, among which were No. 763,259 of June 21, 1904, No. 763,260 of June 21, 1904, and No. 777,273 of December 13, 1904, all to A. E. Cattermole. In the process of each of these patents metalliferous granules are formed and separated from the gangue and fall to the bottom, while the gangue is carried up and away. In No. 777,273, the patentee states:

* * * "The proportion of oil used depends upon its viscosity, the fineness of the ore and other factors, and the consistency and size of the mineral granules desired. The more oil used, the larger, softer, and less numerous the granules. With, say, 10 per cent of oil to the weight of metalliferous mineral a few pasty masses of oil-agglomerated metalliferous mineral matter will generally result. Oil in excess of this may cause all the granules to coalesce into one soft mass. Usually an amount of oil varying from four per cent to six per cent of the weight of metalliferous mineral matter present in the ore yields granules of suitable size, consistency, and specific gravity for ready separation from the gangue in the upcurrent, or other apparatus used for classification."

All of the claims of patent No. 777,273, are restricted to a process by which the oil-coated metalliferous matter is agglomerated into granules and the granules by classification separated from the gangue. And the same is true of all the claims of patents No. 763,259, and No. 763,260, above mentioned. It is also true of both claims of patent No. 777,274, of Dec. 12, 1904, to Cattermole, Sulman and Picard. Shortly before March, 1905, Sulman, Picard and Ballot instructed A. Howard Higgins, one of the plaintiff's experts, to investigate by experiments, certain points in their bearing upon the Cattermole process of granulation. They were as follows:

"(1) Influence of acidity on granulation,
(2) Influence of temperature on granulation,
(3) Influence of speed of Gabbett agitation on granulation,
(4) Influence of ratio of ore to liquor on granulation,
(5) Influence of metallic salts on granulation,
(6) Influence of the size of particles and of the influence of slimes on granulation,
(7) Influence of the amount of oil on granulation."

And the above points were to be determined on "(*a*) oleic acid, (*b*) residuum oils." In consequence of his investigations Higgins made a report March 16, 1905, on granulation as affected by the percentage of oil used, in which he said:

"The effect of diminishing the percentage of oleic acid is to alter the type of oiling; the higher percentages producing granules, and the lower ones froth. Six per cent of the oleic acid on the mineral is sufficient to form good granules without much froth. This froth consists of insufficiently oiled mineral mixed with large quantities of air. As this percentage of oleic acid is decreased, the time for clean-up of the sands is increased and more froth is formed. 0.62 per cent oleic acid on the mineral is insufficient to form any granules and nearly the whole of the mineral comes to the surface, on stopping the cone, as froth. 0.2 per cent acts in the same manner, leaving the coarse sands with rather more mineral in them. (This is 0.1 per cent on Broken Hill ore.) In all cases the oil has been measured in cubic centimeters and the percentage calculated as though they weighed grams, but as the specific gravity of the oleic acid is less than unity, this is not the case, and all percentages will be lower than those actually given."

There was, I think, patentable invention in the discovery thus made in March, 1905. Prior to that time there has been no suggestion in the art that the proportion of 0.1 per cent of oil to ore or of any other fraction of 1 per cent of oil to ore would or might result in successful concentration.

Further, the result reached was an utter surprise. Experiments were conducted with reference to the Cattermole process, and all of the Cattermole patents required the formation and sinking of granules containing the metallic particles, and not their flotation. The teaching of that process was that the metallic particles should go to the bottom and that of the process of the first patent in suit that they should go to the top.

But while the ascertainment that such a minute proportion of oil would effect a successful concentration of ore through a flotation process was a discovery, it was nevertheless of such a character, viewed with respect to the circumstances under which it was made, as to involve invention and confer patentability.

The statutes provide for patenting new and useful inventions and discoveries, but a bare discovery unaccompanied by the exercise of any invention in reaching it or utilizing or reducing it to practice would not justify or support a monopoly in the discovery. In the present case, however, the facts disclose not a bare discovery, but a discovery coupled with invention in usefully applying it. In such cases patents properly may be granted.

The defendant lays much stress upon the proposition that the reduction of the amount of oil in the process for the concentration of ore did not and could not involve patentable invention, but only an ascertainment of the proper degree in which oil should be used, which was readily discoverable by any one competent to conduct or superintend a process of ore concentration; and further, that motives of economy would naturally have suggested a reduction in the quantity of oil to the extent of its excess over what was necessary for the accomplishment of the purposes of the process.

But if such a reduction was obvious, why is it that it was never made prior to the discovery in question? The fact that economy required the use of the least quantity of oil sufficient for the conduct of the process affords cogent evidence that the feasibility of effecting a reduction was not obvious, but properly the subject of patentable invention.

No one to-day understands how the use of only 0.1 per cent of oil operates to secure the mineral froth of the first patent in suit. This is testified to by the experts and is admitted on both sides. If the principle of operation of the discovery is insolvable to the human mind to-day it could not have been predicted or anticipated by the human mind in March, 1905. The fact that the underlying principle of the process was not understood by no means negatives patentability. . . . [Quotations from Diamond Rubber Co. v. Consol. Tire Co. 220 U. S. 428.]

This case is unlike those in which the discovery of the use of an element in a process in the degree insuring the best results is a matter within the competency of those skilled in the art, but, on the contrary, is one where clearly there was patentable invention or discovery in ascertaining the degree. The experiments made with respect to the Cattermole process were initiated with a view to its improvement and the securing of granulation of a higher efficiency. The prosecution of the experiments relating to a sinking and not a flotation process would naturally tend to divert the mind from the contemplation of any process of the latter character. . . . [Quotation from testimony of Mr. Higgins.]

I perceive no escape from the conclusion that the discovery was patentable. To decrease the amount of oil used in an old process, so long as the characteristic mode of operation and result of such process are preserved, even though in less degree, does not as a general rule involve invention. But when the old mode of operation and its result through a decrease in the amount of oil disappear and a new and different result is disclosed, the change ceases to be one of mere degree, and may support a patent monopoly in favor of one whose inventive genius or research has discovered the process. The patentability of the process of the first patent in suit resides in the use of only the minute quantity of oil contemplated by the patent. The reduction of the oil to this quantity effected a change, not merely in the degree, but in the "type of oiling," leading to results which cannot be accounted for on the assumption that a mere change in degree as distinguished from patentable discovery was involved.

The defendant contends that a substantial increase in the amount of oil used will not affect the nature or efficiency of the process of separation, but will only add to the cost by carrying it on with an unnecessary amount of oil. But this position is in conflict with the decided weight of the evidence and with the showing of the experiments conducted by Higgins at and immediately prior to the time of the discovery. It is satisfactorily proven that the process of the first patent in suit, depending upon the selective affinity of the air-bubbles in the mixture for oil-coated metallic particles, that affinity is strongest when the film of oil surrounding the metallic particles is so thin as to be imperceptible to the senses, and that with any substantial increase in the quantity of oil on the metallic particles the character of the process is changed and its efficiency diminished for some reason as yet unrevealed.

A great advance in the art of ore concentration has re-

sulted from the process of the first patent in suit in the efficient recovery of slimes. With the use of that process ore may be so finely ground as to insure the thorough separation of the metallic particles and gangue, and great savings effected. The profit so saved in a single year from the output of the principal porphyry copper mines, including the defendant's, has been estimated by one of the expert witnesses as more than $17,000,000. . . . [Quotation from Moore Filter Co. v. Tonopah-Belmont Development Co., 201 Fed. 532,540.]

Alleged Anticipations

The defendant sets up as part of the prior art to negative invention United States patent No. 689,070 of Dec. 17, 1901, to A. S. Elmore. This patent was for an "Improvement in separating mineral substances by the selective action of oil," and contains but one claim as follows:

"The process for separating metallic and rocky constituents of ore which consists in mixing pulverized ore with water and mixing the ore and water with oil in the presence of an acid, allowing the mixture to rest, whereby the oil having the metallic substances entrapped in it floats at the top of the mixture, and separating the metallic constituents from the oil, substantially as described." * * *

The patent nowhere states the amount of oil which is to be used or the ratio between the weight of the oil and the weight of the ore or its metallic content. It, however, clearly appears from the evidence that the process was what has been termed a "bulk oil process," employing from one to two and a half or three tons of oil to each ton of the pulverized ore to be treated. By reason of the large amount of oil used and the loss of a considerable proportion of it in operation the process was expensive and unsatisfactory. There was but a small recovery from the slimes, probably for the reason that the extremely minute metallic particles contained in them did not yield to centrifugal action employed in the separation as readily as the larger particles.

The Elmore bulk oil process was litigated abroad in Minerals Separation, Ltd., v. British Ore Concentration Syndicate, Ltd., which was an appeal to the House of Lords by the plaintiff herein from a judgment of the Court of Appeal, holding that it had infringed the A. S. Elmore British patent No. 11,307 of 1901, corresponding substantially with United States patent No. 689,070 of Dec. 17, 1901, to A. S. Elmore. The judgment of the Court of Appeal was reversed by the House of Lords. The opinions delivered to that house differed with respect to the validity of the A. S. Elmore patent, but it is to be gathered from the opinions so delivered that the plaintiff herein was held by the House of Lords not to have infringed. . . . [Quotation from Lord Shaw.]

The process of the first patent in suit was also considered in Ore Concentration Company, Ltd., v. Sulphide Corporation, Ltd., in the Supreme Court of New South Wales, and an appeal in the Privy Council of Great Britain. The action in the court below was brought by the owner of and a licensee under British patent No. 10,001 of 1900, to F. E. Elmore, and British patent No. 11,307 of 1901, to A. S. Elmore, to restrain the infringement thereof by a licensee of the plaintiff herein conducting the process of the first patent in suit. The suit was abandoned at the trial with respect to the F. E. Elmore patent, and was dismissed by the Court below as to the A. S. Elmore patent, July 24, 1911.

On appeal the Privy Council affirmed the judgment of the court below, March 6, 1914. The case turned on the questions of the validity of the A. S. Elmore patent and its infringement by the licensee of the plaintiff herein, no reference being made to the first patent in suit or the corresponding British patent, although the novelty of the process was recognized. . . . [Quotation from Lord Parmoor on the general nature of the A. S. Elmore process.]

The judgment concluded with the statement that "their Lordships find that the respondents do not either directly or indirectly use the invention claimed by the appellants, but a process essentially distinct, and that there is no infringement."

While, as already stated, the validity of the first patent in suit was not before the court in either of the British cases, but the question of infringement by the practice of that process, the opinions delivered in the House of Lords, as well as the decision of the Privy Council in declaring that the process covered by the first patent in suit was one "essentially distinct" from the Elmore process, are entitled to much weight. It is too clear for further discussion that the bulk oil Elmore process in no way affects the validity of the first patent in suit.

The defendant sets up as an anticipation of the first patent in suit the Haynes British patent No. 488, of 1860. I am satisfied that the Haynes patent is not an anticipation, and, equally, that as part of the prior art it cannot operate to negative invention. In the first place, aside from all other features, the patent does not limit the quantity of oil, fatty or oleaginous matter to the oil proportions of the first patent in suit, and, secondly, the patent does not require agitation of the pulp other than such as may result from the passage of the same into a "triturating machine." And it appears from the testimony of Dr. Sadtler that without the use of some means to produce agitation not mentioned in the patent its process will not produce mineral froth flotation. Dr. Liebman states that the process is "quite impracticable" and "quite impossible." . . . [Further quotation.]

Two patents to Edmund B. Kirby, No. 809,959 of Jan. 16, 1906, applied for Dec. 14, 1903, for an "Improvement in process of separating minerals," and No. 838,626 of Dec. 18, 1906, applied for Dec. 17, 1903, for an "Improvement in separating tanks," are relied on by the defendant as part of the prior art. The process patent recommends from 25 per cent to 75 per cent of oil to the ore, stating that "preferably the pulverized ore is mixed with three to five times as much water, by weight, and to this is added a sufficient amount of the kerosene-bitumen solution, excellent results being obtained by using one-fourth to three-fourths as much by weight as ore."

It is fair to assume that Kirby would not have specified oil to the extent of from 25 per cent to 75 per cent on the weight of the ore had he deemed it practicable or possible to do with less. An examination of the process patent and of the evidence relating to it shows, I think, that the patent contemplated an oil buoyancy flotation in contradistinction to the metallic air froth of the first patent in suit, and was for a different process, not suggestive of that of the latter, with its economical and successful use of a fraction of only 1 per cent of oil. The Kirby apparatus patent No. 838,626 is for a separating-tank intended for use in the Kirby process. In view of what has been said touching that process the apparatus patent does not call for discussion.

The defendant sets up as part of the prior art a number of patents granted to Alfred Schwarz, but offered in evidence only three of them, No. 807,501 of Dec. 19, 1905, applied for April 19, 1905; No. 807,502 of Dec. 19, 1905, applied for May 27, 1904; and No. 807,503 of Dec. 19, 1905, applied for May 27, 1904. All of these patents relate to the concentration of ores. . . . There is no evidence that any process under either patent No. 807,502 or patent No. 807,503 was carried on as part of the prior art, and evidently each of them requires the use of a larger quantity of oil than the minute proportion required by the first patent in suit; the former stating that "the selective agent being added in sufficient quantity to thoroughly saturate the ore and to make a thick pasty mass," and "the metallic constituents adhering to and being entrapped in the resinous and oil or fat compound will be buoyed up thereby and rise to the top," etc., and the latter, that "the ore is mixed with sufficient of the selective material to make a thick pasty mass, the agitation being continued long enough to bring the selective material into intimate contact with all portions of the ore," and "the mass is then allowed to subside, when the selective material, with the entrapped metallic constituents of the ore, will rise to the top," etc. There is, I think, no evidence or legitimate inference to warrant the conclusion that either of these patents can affect the validity of the first patent in suit.

The defendant also relies upon patent No. 348,157 of Aug. 24, 1886, to Carrie J. Everson, for an "improvement in processes for concentrating ores," as part of the prior art. The patent specifies two methods of conducting the process. It is admitted that the first method requires oil amounting to 5 per cent on the weight of the ore. With respect to the second method it is stated in the patent description:

"I have found three fluid drams of oil abundant for properly moistening two ounces of heavy ore or in the ratio of about a barrel of oil to the ton of ore, the amount being, of course, variable with the relative bulkiness of the ore.

Dr. Liebmann testifies that the oil used in the process was 16.5 per cent of the weight of the ore, and Dr. Sadtler says that the amount of oil so used was from 16 per cent to 17 per cent of the weight of the ore.

The Everson process has never been used commercially and Dr. Liebmann states that it could not be so used; that "it is not a process for large-scale operations"; but that there was a possibility of its application to gold and silver in small quantities. Dr. Sadtler expresses no opinion upon the applicability of the Everson process to the concentration of ore on a commercial scale, and states, in substance that he had never practised the Everson process in either of the methods disclosed in the description of the patent.

The defendant argues that in the Everson process the concentrate "could not possibly float by the bulk oil flotation principle, for the simple reason that the amount of oil was insufficient for that purpose," that with the use of only 17 per cent of oil no bulk oil flotation is possible; and that the process "could not have resulted in surface tension flotation, skin flotation or film flotation, so-called, for the simple reason that the conditions for that form of flotation were absolutely wanting."

But this contention fails, I think, to negative patentable invention in the process of the first patent in suit. I am not satisfied by any experiment or demonstration made in the case that the process described in the Everson patent would produce the economical and efficient concentration secured by the process of the first patent in suit. Certainly, were there nothing else, a reduction in the quantity of oil from 17 per cent or even 5 per cent to a fraction of 1 per cent on the weight of the ore, under circumstances similar to those attending the discovery of the sufficiency of that minute proportion for successful metallurgical operations would be sufficient to confer patentability.

An analogy is furnished in Loom Co. v. Higgins, 105 U. S. 580, where Mr. Justice Bradley, delivering the opinion of the court, said:

"It is certainly a new and useful result to make a loom produce 50 yards a day when it never before had produced more than 40; and we think that the combination of elements by which this was effected, even if those elements were separately known before, was invention sufficient to form the basis of a patent."

The defendant also relies upon a newspaper article taken from the *Daily Herald Democrat*, of Leadville, Col., Oct. 30, 1889, referred to as "Fryer Hill Publication," and an article taken from the *Engineering and Mining Journal* of Nov. 10, 1890, referred to as "Criley and Everson Publication," as part of the prior art. It appears that both articles refer to tests or experimental applications of the process of the Everson patent, with some slight modifications. Neither of these articles contain anything rendering it necessary to add to what has been said in direct connection with the Everson process.

Much stress is laid by the defendant upon an article in the California *Journal of Technology* of November, 1903. This article was prepared by three young men, students in the class of 1903 in the mining department of the University of California, and is entitled "Experiments on the Elmore process of ore concentration." This article is suggestive, but cannot, I think, be justly treated as negativing the exercise of invention with respect to the process of the first patent in suit.

The experiments were laboratory tests and did not disclose or suggest the idea that such a minute quantity of oil as one-tenth of 1 per cent, or any fraction of 1 per cent, on the weight of the ore could be efficiently and successfully employed in ore concentration. There were a number of tests with respect to the concentration of molybdenite ore with percentages of oil to ore running from 2.1 per cent to more than 100 per cent, with the result that the highest extraction of molybdenum sulphide was obtained by the use of 8.9 per cent of oil; the extraction in that case being 75 per cent as against an extraction of 43.5 per cent obtained by the use of 2.1 per cent of oil. The teaching of these tests was that 2.1 per cent of oil was less efficient than the use of 8.9 per cent, and the article as a whole, far from suggesting the possibility of the use of only a fraction of 1 per cent of oil points to an opposite conclusion.

The defendant contends there is nothing new in the employment of only a fraction of 1 per cent of oil relative to the weight of the ore in the process of the first patent in suit, for the reason that, as alleged, an equally small proportion of oil was used in the process of the Cattermole Patent No. 777,273, mentioned in the first patent in suit.

The Cattermole patent mentions from 4 to 6 per cent in weight of oil to the weight of the metalliferous mineral present in the ore, and consequently, under the Cattermole process the amount of oil to be used depends upon the weight of the metalliferous mineral, and not upon the weight of the entire ore, and there is evidence to the effect that the larger part of the copper ores mined and concentrated in this country contain about 2 per cent of copper. Hence the argument is made by the defendant that the weight of oil employed in the Cattermole process is only from 0.8 per cent to 0.12 per cent of the weight of the copper contained in the ore, and that any proportion of oil less than 1 per cent of the weight of the ore comes within the quantity mentioned in the first patent in suit, namely, "a fraction of 1 per cent on the ore."

This contention ignores the following statement in the description of the Cattermole patent now considered:

"In certain cases, as where but little mineral is present in the ore, to increase the nucleating or granulating factor pulverized mineral matter obtained in a previous operation or other matter having an affinity for oil from a different source may be introduced into the ore, or a portion of already granulated and separated mineral matter may be returned to maintain the necessary amount of mineral in the ore under treatment."

It is evident that the weight of "pulverized mineral matter" introduced to "maintain the necessary amount of mineral in the ore under treatment" is, for the purpose of determining the necessary amount of oil to be added to "the weight of metalliferous mineral matter present in the ore." Such must be the meaning of the patent or it is insensible. And this accords with the requirement in the seventh claim of "adding particles of material having an affinity for oil to assist in the formation of granules of oil-coated particles."

The defendant has made no demonstration, as might have been done, of the amount of oil required by the Cattermole process in its application to lean copper ores, but indulges in speculation and conjecture on that point.

The defendant contends that in the Cattermole process of the above patent there were necessarily two degrees of agitation of the mixture; the first being violent and the second gentle. On the assumption that two degrees of agitation were required in the Cattermole process; first, violent agitation of the mixture in order to bring the oil into intimate contact with the mineral particles; and, secondly, the subjection of the mixture to a slower or rolling form of agitation to cause the agglomeration of the oiled metalliferous particles and the formation of granules, it by no means follows that with the omission of the second step the mineral froth of the process of the first patent in suit would have been formed, had there been in the mixture oil in excess of the proportions contemplated by that patent.

And if it be further assumed that the mixture containing oil and other elements in Cattermole proportions can first be violently agitated so as to produce a froth and then slowly agitated so as to produce granules, and again violently agitated so as to destroy the granules and restore the froth, and so on by alternation, and that, the mixture remaining the same, the production of froth on the one hand, or granules on the other, is simply a matter of manipulation, it is not to be inferred that the froth so formed with Cattermole proportions of oil would be the froth of the first patent in suit.

Dr. Liebmann, for the purpose of distinguishing between the Cattermole process and that of the first patent in suit, during the trial conducted two experiments, identical in their nature, save that in one a larger amount of oil was used than in the other. In the former case granules were formed which sank; and in the latter a mineral froth was formed, the agitation and other factors being the same; 3.6 per cent of oil and 0.1 per cent of oil were respectively used in the two experiments. Both were performed in the same apparatus with similar materials and manipulation. These experiments served to show that the variation in the amount of oil used, other things being equal, may result in the formation of the mineral froth of the first patent in suit, or in the formation and sinking of the granules of the Cattermole process. In this connection it is to be observed that the Cattermole patent in its descriptive portion states:

"With certain ores it may be preferable to use in some stages of the process a rolling form of agitation, as in cylinders or barrels, to obtain good granulation of the mineral."

The description of the patent nowhere specifies that its process is necessarily dependent upon two degrees of agitation, one violent and the other slow or rolling, and in none of the seven claims of the patent, with the exception of the fifth, is such a requirement mentioned or suggested. In that claim only is there a provision for "further agitating the mass to increase the size of the granules," and even in that claim there is no suggestion of a difference in degree between such further agitation and the agitation which has preceded it. For the foregoing reasons I think that the contention of the defendant that the quantity or proportion of oil used in the Cattermole process was not materially in excess of that used in the process of the first patent in suit, and that, not a difference in the quantity of oil, but a resort to two degrees of agitation was essential to the formation of Cattermole granules, cannot be sustained.

The defendant also relies upon two patents granted to Alcide Froment; one of them being British patent to Henry Harris Lake, communicated by Alcide Froment, No. 12,778, of 1902, and the other an Italian patent to Froment, No. 63,723, the specification of which is dated May 20, 1902.

The weight of the evidence is that the quantity of oil to ore necessary for the conduct of the process specified in

the patent would amount to from 12 per cent to 15 per cent of the weight of the ore, and this seems to accord with the statements in the patent that a "kind of metallic magma" is formed and that "the metallic spherules pressed one against the other, will become grouped in a magma clearly separated from the remainder of the liquid."

These statements, I think, are inconsistent with any idea that under the Froment process the metallic particles were coated with oil of the extreme thinness, characterizing the process of the first patent in suit; the thickness of the film in that process, according to scientific evidence, being only one one hundred thousandth part of an inch and imperceptible to the senses, as compared with a thickness of from sixteen to thirty-two one hundred thousandths of an inch in the Cattermole process and from eighty-eight to two hundred and forty one hundred thousandths of an inch in the Froment process. . . . [When the Froment British patent was assigned to Ballot there was handed to him] a "description and instructions for the concentration of ores" under the Froment process. It is dated Dec. 29, 1903. The instructions recommend the use of oil in proportions varying from 1 per cent to 3½ per cent, according to the different percentages of metal in the ore.

Notwithstanding the low percentage of oil mentioned in the Froment description, I have reached the conclusion that it contained no disclosure of the process of the first patent in suit. The evidence on the subject of the Froment description is voluminous and conflicting. but there are facts and circumstances which have satisfied me that the process of the first patent in suit was not discoverable from that description by men skilled in the art of ore concentration.

There is uncontradicted evidence that Sulman, Picard and Ballot, after the assignment of the Froment British patent, and the receipt of the Froment description and instructions, made persistent efforts to operate the Froment process successfully, but only met with failure, and that the model apparatus sent by Froment to Ballot was treated as worthless and discarded or "scrapped." Sulman, Picard and Ballot were scientific men of large experience in the art of ore concentration, and had the Froment patents or description disclosed or suggested the process of the first patent in suit, it is to be assumed that they would have utilized it instead of prolonging their attempt until March, 1905, to perfect granulation under the Cattermole process. The fact that they did not utilize it affords the strongest evidence that the Froment description did not suggest a process in which the minute quantity of oil required by the first patent in suit could be successfully used in ore concentration.

The defendant relies on patent No. 793,808, of July 4, 1905, to Sulman and Picard, for "Improvements in or relating to ore concentration." . . . [Quotations from patent.]

There are certain features in this process as described, similar to features in the process of the first patent in suit. The amount of oil coating the metallic particles being insufficient to raise them through the flotation power of the oil alone, gaseous bubbles, whether generated in the mixture, or introduced into it through the perforated spiral coil, attaching themselves to the oiled metallic particles, rise to the surface with those particles, so as to be removed by skimming or other suitable means, the gangue particles remaining in the main at the bottom of the vessel containing the mixture.

This process patent, issued to Sulman and Picard upon an application filed Oct. 5, 1903, affords cogent circumstantial evidence of the patentability of the process of the first patent in suit. I have been unable to read the description of the patent immediately under consideration without reaching three conclusions; first, that Sulman and Picard had conceived an idea, though imperfect, of an air flotation of the metallic particles; secondly, that they had no conception whatever of the possibility of conducting such a process with the minute quantity of oil specified in the first patent in suit; and thirdly, that they contemplated the use of a very much larger proportion of oil.

In view of the fact that both patentees in No. 793,808, were two of the three patentees of the process of the first patent in suit, it is so improbable as to amount to a moral impossibility that for nearly a year and a half after the filing of the application for patent No. 793,808 they should have devoted their attention and efforts to the solution of the problem of the proper quantity or proportion of oil to be used in securing improved granulation in the Cattermole process, and have been astonished at the making of the discovery in March, 1905, if they had recognized or believed that an economical and efficient process of ore concentration could be carried on by the use of oil amounting to only a fraction of 1 per cent. Any further discussion of patent No. 793,808, I think, is unnecessary.

Further Discussion of Validity of First Patent

I have found nothing in the prior art to anticipate the process of the first patent in suit or to negative invention. Objection has been made that the disclosures of the patent are not sufficient, in that the application of the process to different ores necessitates some difference in treatment involving a variation in temperature, or in the amount of acid or of oil, and the patent omits to specify the degree or amount of such variation with respect to the treatment of the different ores. But to require of an inventor such a specification would be to demand an impossibility. The patent recognizes that different ores may require a different treatment. . . . [Quotation from patent.]

And claims 1 and 12 mention oil amounting to "a fraction of 1 per cent." A close or exact adjustment of quantities and proportions of oil in the treatment of different ores within the limits prescribed in the patent is a matter calling, not for the exercise of inventive genius, but for the skill of the metallurgical engineer conducting or superintending the operation. [Quotation from Mowry v. Whitney, 14 Wall, 620.]

Some embarrassment in the treatment of this case has been caused by the use of different adjectives and descriptive phraseology as applied to the same thing. If a patent for a process of ore concentration, or any other process, clearly sets forth the ingredients and the practical steps to be observed in conducting it the misuse of terms as applied to the operation of natural laws involved in the process is immaterial. In the administration of justice it is the aim of courts to deal with substance and not to be influenced by mere form not calculated to mislead as to substance; and where a material and substantial thing is plainly identified in the patent claims and description a mistaken misnomer is harmless and negligible. Inventors are not required to understand the natural laws under which new and useful results are obtained from ingredients, elements, apparatus and manipulation requisite for the conduct of the process.

There are occult laws, unknown and inexplicable, to which tangible results must be attributed. In the nature of things an inventor, so long as he clearly sets forth the practical means and steps for securing those results, does all that the law requires or can reasonably be expected of him. So, it is unimportant that to the same thing one name may be applied by one person and a different name by another, the identity clearly appearing. The truth of this statement has been strikingly exemplified in this case in the language of patents and other publications, judicial decisions, the oral testimony and the arguments of counsel.

During the trial a large number of experiments were made for the purpose of illustrating ore concentration processes described in patents and other printed publications of the prior art. Such experiments are illuminating and helpful, or deceptive and misleading, according to the conditions under which they are performed. As a general rule, in such experiments processes of the prior art should be illustrated by means of apparatus of the prior art in which such processes were conducted at or about the time of invention and under the conditions then understood and observed. To construct apparatus long after, and in view of subsequently acquired knowledge, in order to show a prior process, tends to produce embarrassment and confusion touching the nature and operation of the process inquired into. . . . [Quotation from Naylor v. Alsop Process Co., 168, Fed. 911, and from Schmertz Wire Glass Co. v. Western Glass Co., 178, Fed. 977.]

The material question for the court is not whether any given apparatus is capable, under manipulation employed in view of existing knowledge, of carrying on the prior process inquired into, but whether the process was carried on as part of the prior art, and, in case of an ore concentration process, by way of illustration, under what conditions as to ingredients, strength and extent of agitation and other essential factors; and only so far as those conditions are reproduced and faithfully observed in demonstrations in court, due allowance being made for the difference in the requirements of mill operations, is the experiment entitled to probative force. The difference between the conduct of the process in the mill and the necessarily interrupted or broken character of the process as disclosed in experiments in court and laboratory tests in subsequently constructed apparatus must be borne in mind in determining the weight to be given to such experiments or tests.

Claim 9 of First Patent Invalid

On the whole I am satisfied that the first patent in suit must be sustained as to claims 1 and 12, but not as to claim 9. The two former are definite, specifying and limit-

ing the amount of oil to be used; claim 1 mentioning "a small proportion . . . amounting to a fraction of one per cent on the ore," and claim 12 "a fraction of one per cent of oil on the ore." Claim 9 mentions "a small quantity of oil." This is so indefinite as to render the claim void, unless on consideration of the patent as a whole the claim can by construction be limited to the use of oil amounting to only a fraction of one per cent.

The patentability of the process of the first patent in suit resides in the use of oil in the extremely minute proportion disclosed in the descriptive portion of the patent to effect separation of froth with its metallic particles from the remainder of the mixture by flotation. The amount there disclosed is not in excess of "a fraction of one per cent on the ore" and may be only one-tenth of one per cent of the ore, or even less.

If, then, by construction claim 9 should be so limited as to be restricted to the use of oil amounting to only a fraction of one per cent on the ore, that claim is in substance, though not in exact phraseology, the same as claim 1 for the reason that in any event from the nature of the invention it would be necessary to read "by flotation" into claim 9, if in other respects valid. But a limitation by construction producing such a result is inadvisable.

It is suggested by one of the plaintiff's counsel in his consideration of claim 9, that one for the purpose of securing immunity from the consequences of infringement might use an oil useful in the process, and add to it an oil not useful as applied to his particular ore, and, on being sued for infringement contend, "I am using 1.1 per cent of oil. I did not infringe. I am using more than a fraction of 1 per cent of oil." But the existence of this possibility does not, I think, warrant such a construction of claim 9 as is urged; for the disclosure of the patent does not extend to the use of 1.1 per cent of oil, but is limited to a fraction of 1 per cent. If it be assumed, however, that the claims in suit contemplate and require the use of efficient, as distinguished from inefficient, oil, and if in the case suggested an inoperative oil should be used by way of addition to the efficient oil so contemplated and required it might be a question, upon which, however, no opinion is here expressed, whether the addition of the inoperative oil to the efficient oil could be treated as an increment to the amount of oil so contemplated and required, operating as a shield to protect the wrongdoer. But this question would arise in a suit based upon claim 1 or 12, as well as in a suit based upon claim 9, were it proper by construction, in order to save it, to limit "a small quantity of oil" to a quantity of oil amounting only to a fraction of one per cent on the ore, and therefore fails to require or justify the suggested limitation of claim 9, without which it must fail.

Infringement of First Patent

On the question of infringement of the first patent in suit I have no doubt. It was practically admitted by counsel for the defendant in opening the defense that it had infringed the three patents in suit by its operations at Miami within four months next before the filing of the bill; he stating "in the first installation which was made at Miami, we make no serious contention that it did not represent the operations set forth in the three patents in suit." It appears that the infringing operations were carried on in apparatus built in imitation of the plaintiff's standard machine.

But the defendant denies that it infringed by its concentration of ore in its pneumatic flotation plant through its practice of the process of patent No. 793,808 of July 4, 1905 to Sulman and Picard, hereinbefore discussed, as modified by the use of what is known as the Callow cell. Counsel for the defendant, however, stated with respect to the process of the patents in suit and the process as carried on by the defendant under the Sulman and Picard patent, with the apparatus of the Callow cell:

> "The broad principles are the same in both. In both we have the pulp, consisting of ore held in suspension in water. In both the water is modified to lower its surface tension. In both the buoyancy comes from air-bubbles."

The defendant in its operations also used the minute proportion of oil mentioned in the first patent in suit. It does not use acid in its process; but this fact is immaterial so far as the question of infringement is concerned for the reason that it appears both from the claims and the description of that patent that the use of acid is optional, the description stating that "the water in which the oiling is effected is preferably slightly acidified," and claims 1 and 12, as well as claim 9, unlike a majority of them, not requiring acid. The defendant's counsel also stated that the difference between its process and that of the complainant "comes after the air-bubbles have attached themselves to the mineral particles."

I do not think there is any such difference between the processes as to negative infringement. It was in substance admitted on the part of the defendant that if the first patent in suit is a pioneer patent and properly drawn the operations carried on at Miami were an infringement. Whether that patent is technically a pioneer patent or not, it certainly was highly meritorious and, I think, partook of the nature of a pioneer patent so far as the very successful use of oil amounting to only a fraction of one per cent is concerned. Its claims merit much liberality of construction and when so construed embrace the operations of the defendant at Miami.

The purpose of each process is the concentration of the ore through the separation of the metallic particles from the gangue. In the plaintiff's process the separation is effected through the rising of air-bubbles to which are attached the metallic particles, through the mixture to the top, and the formation of a froth or scum on the surface, which can by simple means be removed with the contained metallic particles. In the defendant's process the separation is effected through the rising of air-bubbles to which are attached the metallic particles through the mixture to the top and the floating away into a launder of either the original bubbles to which the metallic particles were first attached or succeeding and oncoming bubbles which have caught and buoyed up to the surface the metallic particles escaping from bursting bubbles. By the use of a launder a recovery of the metallic particles is readily effected.

The defendant contends that since its abandonment of its original infringing process at Miami above referred to, it has not and does not infringe the first patent in suit, for the reason that it does not in its process produce the coherent and permanent froth of the process of that patent. It appears from the evidence, it is true, that the bubble froth in the defendant's process is not as coherent and permanent as the froth of the process of the first patent in suit; but both are mineral froths, and that of the defendant is sufficiently permanent to effect through air flotation an efficient separation of the metallic particles from the rest of the mixture. Air-bubbles, however produced, in water not modified or contaminated—pure water—on reaching the surface will immediately collapse, and the formation of bubble or air froth is impossible; but air-bubbles in modified water will not instantly disappear on gaining the surface. The degree of their permanency after reaching the top largely depends on the degree of modification of the water.

There has been much expert evidence relating to the subject of surface tension to the effect that in the case of pure water it is so great as to cause the instant collapse of bubbles of air rising to the surface; but that through modification of the water, the tension is so reduced in force as to permit the continued existence for a greater or less period of bubbles of air reaching the surface. The water in the ore pulp of the defendant's process is strongly modified and of necessity the bubbles on reaching the surface do not and cannot instantly disappear; but, on the contrary, in accordance with the operation of natural laws about which there is no conflict, persist and continue on the surface as a bubble or air froth. But whatever may be the true explanation of the phenomenon of the continuance and disappearance of escaping bubbles, the fact remains that the defendant's process discloses a froth consisting of bubbles which have passed through modified water to the surface of the mixture, and float thereon, and with their freight of metallic particles flow over the edge of the containing vessel into a launder, thus effectively separating the valuable mineral from the gangue particles. Coherency and permanency in a froth admit of degrees, and such a degree as insures by air flotation efficient and final separation between the metal and the gangue, whatever may be the duration of the froth, comes within the process of the first patent in suit.

The defendant further insists that its process lacks violent agitation which it claims is an essential of the process of the first patent in suit. Each of the twelve claims of the patent mentions as an element of the process "agitating the mixture," but not one of them mentions violent agitation. It is, however, urged that as the descriptive portion of a patent for a process must contain a full and fair disclosure of the patented invention the claims must be read in the light of the description, and as violent agitation is included in the description the claims with respect to agitation must be limited to violent agitation. But the description nowhere mentions "violent agitation" or uses any equivalent expression. It mentions "vigorous agitation," and states that in the case of the application of the patented process to an ore containing "ferruginous blende, galena, and gangue consisting of quartz, rhodonite, and garnet,"

the mixture is "briskly agitated." It also describes as a part of the apparatus for carrying on the process a "rotatable stirrer." But I do not find in the description any specification of any rate of speed for the rotatable stirrer, or of any standard for the determination of what constitutes a "vigorous agitation" of the mixture, or a specification of any test for ascertaining whether the mixture is "briskly agitated."

All these matters were left to the judgment and skill of the metallurgical engineers conducting or superintending the operation of the process, involving empirical investigation to reach the best results. The strength of agitation referred to in the description clearly admits of different degrees, varying from one another in the application of the process to different ores and under changing conditions. There is no room for doubt that agitation of the mixture in the process of the defendant is sufficiently vigorous or brisk to insure efficient ore concentration by an air flotation process such as is accomplished by the complainant by agitation under the process of the first patent in suit. This being true the use of mere adjectives in the descriptive portion of the patent with respect to agitation is unimportant.

In order that the bubbles in the pulp mixture may come in contact with the metallic particles there must be such movement between them as cannot be wholly accounted for by selectivity as between them, and their movement so far as not accounted for by selectivity is the result of agitation; and whether such agitation results from the stirring or beating of the mixture or the forcing or admission of air in it is immaterial; for what this court is dealing with is not an apparatus patent but a process patent.

Callow Pneumatic Flotation

Patent No. 1,104,755 of July 21, 1914, to John M. Callow, covers apparatus relating to ore concentration. The evidence shows that the defendant in its concentration of ore in its pneumatic flotation plant employs the process of patent No. 793,808 of July 4, 1905, to Sulman and Picard, hereinbefore discussed, as modified by the use of certain apparatus substantially the same as a portion of the apparatus, the operation of which is described in the above-mentioned Callow patent, as follows:

"From the foregoing, it will be understood that I employ no mechanical propellers for producing the necessary agitation and beating into the froth the large volumes of air, but that I depend upon the compressed air admitted through a porous body which has the function of splitting up the air into innumerable fine streams and distributing these fine streams over and into substantially the entire surface of the pulp, whereby immediately upon the introduction of the air a more or less violent agitation or ebullition takes place and a froth begins to generate and to finally rise and form on the surface of the pulp."

The character of the agitation above described is also clearly recognized in the claims of the Callow patent.

The combination of claim 1 of the first patent in suit contains the following elements: (1) Mixing powdered ore with water; (2) adding a small proportion of an oily liquid having a preferential affinity for metalliferous matter (amounting to a fraction of one per cent on the ore); (3) agitating the mixture until the oil-coated mineral matter forms into a froth; and (4) separating the froth from the remainder by flotation.

The elements in the combination of claim 12 are (1) separating the mineral from gangue by coating the mineral with oil in water containing a fraction of one per cent of oil on the ore; (2) agitating the mixture to cause the oil-coated mineral to form a froth; and (3) separating the froth from the remainder of the mixture.

The elements entering into the defendant's infringing process are the same as those of claims 1 and 12 of the first patent in suit. There is no escape, I think, from the conclusion, not only that the defendant infringed the first patent in suit by carrying on the process of ore concentration in its first installation at Miami in apparatus in imitation of the plaintiff's standard machine, but also has infringed and is infringing the same patent by carrying on the process of ore concentration in its pneumatic flotation plant at the same place.

Validity and Infringement of Second Patent

The second patent in suit, No. 962,678, of June 28, 1910, to Sulman, Greenway and Higgins, is for "improvements in ore concentration." The patentees state that the object of the invention is "to separate certain constituents of an ore such as metallic sulfids from other constituents such as gangue when the ore is suspended in a liquid such as water." This patent is distinguishable from the first patent in suit; the object of the invention of that patent being, as stated, "to separate metalliferous matter, graphite, and the like from gangue by means of oils, fatty acids, or other substances which have a preferential affinity for metalliferous matter over gangue."

It appears from the patent as a whole that "other substances which have a preferential affinity for metalliferous matter over gangue" are restricted to those of an oily nature. Such substances as mentioned in the various claims of the patent are "an oily liquid," "an oily substance," "oleic acid," "oleic soap solution" and "oil." No other frothing agent than the above substances enters into the process of the patent. The essence of the invention of the first patent in suit was the restriction of the "oily substance" to "a fraction of one per cent on the ore." In the process of the second patent in suit no oil, fatty acid, or oily substances is introduced into the mixture. . . . [Quotations from patent.]

It will be observed that no one of the claims of the second patent in suit required as an element an oily substance or liquid, as is essential in the process of the first patent in suit, and all of the claims relied on require the introduction into the mixture of "a small quantity" of a "mineral frothing agent" or an "organic mineral frothing agent." The amount of the mineral frothing agent employed in the process is not confined to a fraction of 1 per cent on the ore, but must be a small quantity, evidently to be determined by the metallurgical engineer conducting or superintending the operation according to the requirements of the different ores.

The novelty of this invention is to be found, not in any restriction of the amount of the mineral frothing agent to any stated proportion, for there is none, but in the fact that a mineral frothing agent as the means of separating the metallic particles from the gangue is substituted for the oil, fatty acid or other oily substance essential to the process of the first patent in suit. Such substitution has produced successful results, and, I think, involved invention.

Frothing agents had theretofore been used in ore concentration, but not in the absence of an oily ingredient. Even were the grounds on which the validity of the patent can be sustained less clear, it should have the benefit of the presumption of validity arising from the grant of letters. That the defendant has infringed the claims in suit of the second patent is established by the evidence.

Invalidity of Third Patent and Conclusion

The third patent in suit No. 1,099,699 of June 9, 1914, to H. H. Greenway, assignor to plaintiff, is for "Improvements in the concentration of ores." In the description it is stated:

"This invention relates to the concentration of ores and has been applied in practice to the concentration of copper ores, the object being to separate certain constituents of the ore, such as copper sulfids (for example, in the form of copper pyrites) or metallic copper (natural or reduced), from other constituents such as gangue when the ore is suspended in a liquid such as water. The present process is a modification of the invention described in U. S. Patent to H. L. Sulman, A. H. Higgins and myself, No. 962,678, granted June 28, 1910. The process therein described is applicable generally to the recovery of metallic sulfids and like flotable metalliferous matter and in the case of lead and zinc sulfids to which the process has been largely applied it is necessary for efficient working that the pulp should be slightly acidified, and in most cases in practice the pulp is heated. It is now found that with copper ore such as an ore containing copper pyrites effective separation is obtained in the cold without the use of acid by employing as mineral frothing agents aromatic hydroxyl compounds such as phenol, cresol, or mixtures containing the same. The process of concentrating ores containing copper sulfid or metallic copper according to this invention consists in mixing the powdered ore with water containing in solution a minute quantity of aromatic hydroxyl compound such as phenol or creosol but without mineral acid and in the cold, agitating the mixture to form a froth and separating the froth."

The first twelve claims of the patent are in suit, but it is unnecessary to set them forth in full. I do not find any element of patentability in the process of this patent. It is stated in the description that the process can be carried on "without mineral acid and in the cold," and "is carried out in the cold and no acid is added to the pulp."

Under the second patent in suit the use of heat is optional, and no patentability can be attributed to the process of the third patent in suit on the ground that the process is carried on in the cold or without heat; for patentability can never result from the mere omission to do something, the doing or not doing of which is optional.

There is a question on which a difference of opinion has been expressed, whether in the process of the second patent in suit the use of acid is also optional. The description in the patent considered alone required the use of acid; but while five of the nine claims mention "acidified water," the remaining four do not refer to acid. It is not altogether clear to me under these circumstances whether the use of acid is not optional. But however that may be, I think that, in view of the processes of the prior art an omission to use acid in the process of the third patent in suit cannot confer patentability upon it.

Many actual or supposed inconsistencies or contradictions in the testimony have been commented on by counsel, but, while they have been considered, I do not deem it necessary to a proper decision of this case that they should be discussed in this opinion.

A decree in accordance with this opinion may be prepared and submitted.

Electric Furnace Steels

A conference on the above subject which brought out considerable interesting discussion was held during the week of the Exposition of Chemical Industries in New York under the auspices of the American Chemical Society. Dr. John A. Mathews, president of the Halcomb Steel Co., presided.

Dr. Mathews compared the ancient and modern methods of iron and steel manufacture, emphasizing his remarks with a series of lantern slides. He pointed out that the modern process differed very little from that of the sixteenth century, the development of the industry having been almost entirely in machinery for handling the metal. The electric furnace is the most modern type of machine for the production of various kinds of steel and is being operated with considerable success by many manufacturers. Reproductions were shown of several types of electric furnaces, including the Heroult, Rennerfelt, Snyder, Roechling-Rodenhauser, Grönwall-Dixon, and others. A view of the first Heroult furnace installed in the United States at the Halcomb Steel Co.'s plant was also shown. This furnace is still operating and is the only single-phase Heroult now in operation in the country. In reply to a question from Professor Howe whether for certain purposes crucible steel is still decidedly better than electric steel, because the crucible steel is not heated to such a high temperature, Dr. Mathews said that the conditions are such that the electrically melted metal in the ladle, ready to pour, is not materially different from well-melted crucible steel. The principal difference, as Professor Richards has pointed out, is that the crucible steel is made in small ingots, which is somewhat of an advantage.

Dr. Mathews said that crucible furnaces are primarily not suited for making alloy steels. In the electric furnace the cost is lower, the necessary additions can be made in the furnace itself, and heating can be continued as long as desired without any material loss. The advantages of the electric method in making high-speed steel are not as marked as in the cheaper alloys.

In discussing the subject of working on cold and hot charges Mr. Humbert said that practically all the smaller furnaces use cold charges, the larger furnaces, such as of 15 and 20-ton capacity, operating on molten metal.

Professor Richards said that in a Norwegian plant steel ships are broken up and melted in an open-hearth furnace and the charge then transferred to the electric furnace. Even with electricity at $6.40 per horsepower year, they found it cheaper to use a combination process and operate the open-hearth with coal at $6 a ton. In discussing the stated superiority of ordinary carbon steel made in the electric furnace over that made in the open-hearth furnace, Professor Richards thought the dead-melt and the deoxidation possible in the reducing atmosphere of the electric furnace were important factors. There is also an opportunity in the electric furnace for the slag inclusions in the steel to separate out. Crucible steel and electric furnace steel are alike in that they are freer from foreign materials than either the open-hearth or Bessemer.

Dr. Mathews read a letter from K. W. Zimmershied, metallurgist of the General Motors Co., Detroit, Mich., in which it was stated that it was the writer's experience that electric furnace steels are generally freer from non-metallic inclusions than open-hearth or bessemer, that they seem to have a considerably wider forging range, and also seem to have a wider hardening range, *i.e.*, could be reheated to higher temperatures without becoming coarser grained than open-hearth or Bessemer steels.

Professor Richards thought the most efficient and satisfactory process for manufacturing alloy steels would in the future prove to be a combination of the Bessemer, open-hearth, and electric furnace, the steel being treated in each in the order mentioned. This is known as the triplex system. It developed later that the U. S. Steel Corporation has already installed a fifteen-ton triplex system at Joliet, Ill., and has under construction two other units of the same type, having a capacity of twenty tons each. Dr. Richards thought the question of refractories demanded considerable attention and asked whether zirconium oxide was being used in any way.

The question of power costs for electric furnaces took up considerable time. Mr. Morgan Smith of the Detroit Edison Company said that it was the ambition of the company to produce electric power with steam plants at such a low cost that it could not only compete with water power current but could undersell it. He intimated that the time would not be far in the future when this ambition would be realized. Professor Richards thought the power question was a secondary one with most electric furnaces except when making plain low-carbon steel to compete with open-hearth. Mr. Berry said the power companies did not fully appreciate the value of the electric furnace industry to them. Mr. Crosby said the central stations have been investigating the question more fully during the last three years.

In discussing uranium steel Mr. Hoffman said that it made very good tools, but that they did not seem to hold their efficiency. Two-tenths of uranium is supposed to take the place of 12 per cent tungsten. Dr. C. M. Johnson said from a few experiments he had made with low-carbon steels containing 0.3 per cent uranium, it did not seem that the material promised to be of any value, but that there might be other combinations which made a good high speed steel.

Milling of Ores.—The Hardinge Conical Mill Co., New York City, has issued an attractive little book on the uses of Hardinge mills in the milling of ores.

The **Asbestos Protected Metal Company** announces that Mr. William H. Cummings, formerly of Providence, R. I., has become associated with its Waugh glazing department.

A Large-Capacity High-Voltage Transformer.—Some interesting insulating tests were recently carried out at the University of Minnesota in conjunction with the Minneapolis General Electric Co., by means of a new high-voltage transformer, capable of giving a secondary voltage of 300,000 volts. The tests were made on insulators to be used on the Minneapolis General Electric Company's new 100,000-volt line from Chippewa Falls. The tests, which were conducted by Prof. W. H. Springer, were accompanied by a brilliant display of fireworks and a strong smell of ozone. A continuous heavy spark more than 3 ft. long was maintained in one test for several minutes. The insulators tested consisted of corrugated glass disks mounted on a rod of special insulating material. The transformer was built by the C. H. Thordardson Company of Chicago, and took two years to construct. It is submerged in 14 barrels of insulating oil in a steel tank, which is 7 ft. long, 5 ft. wide and 7 ft. high, with two terminals protruding 3 ft. from the top. The weight when full of oil is a little more than 5 tons.

Specifications for Single and Multiple Effect Evaporators *

By Otto Mantius

There is practically no literature which will give reliable information about evaporators so that chemists and engineers who have to purchase such an equipment can form their own opinion on the subject. According to my knowledge, and I have searched carefully the English, German and French technical literature, there are no books giving such information. Hausbrand only gives the physical laws and formulas, but no practical data for the construction of evaporators. Forster's book has only a collection of patents. Therefore the prospective buyer must entirely rely on the information contained in the catalogs published by the manufacturers of evaporators, and it is hardly possible to make up specifications from this information unless the purchaser is thoroughly familiar with all evaporating problems.

The object of this paper is to give some of the most important points which should be determined and considered when purchasing evaporating equipments.

QUANTITY AND NATURE OF SOLUTIONS

Unless the liquid to be treated is well known, and has been handled in evaporators before, it is absolutely necessary for the purchaser to give complete information to the manufacturer about the nature of the liquor. He should state the amount of liquor to be handled, the temperature and specific gravity of the feed liquor, and the density of the final product. If the solutions are of complex nature, it is best to give a complete analysis. If salts are to be separated from the solution, the quantity of this salt should be given. If possible, a sample of the liquid should be sent to the manufacturer, so that it can be tested in their experimental station.

It should be stated if the evaporator is to work eight, twelve, or twenty-four hours per day, and six or seven days per week. In case the equipment is to be operated continuously, an extra pan should be provided for, so that repairs can be made without shutting down the whole plant. Besides, the evaporator must be able to handle seven days' work in six days, and the purchaser should provide twenty-four hours storage capacity for both weak and heavy liquor.

NUMBER OF EFFECTS

If the evaporator is to be operated with exhaust steam entirely, the number of effects will depend on the quantity of steam available. I have known a case where quite expensive triple-effect evaporator was installed, and it was found afterwards that sufficient exhaust steam was available to do the work in a single-effect evaporator, which naturally would have been very much cheaper. If live steam is to be used entirely, the number of effects should be found by comparing the saving effected by one or two extra pans, as compared with the interest, depreciation and repairs required for this additional machinery.

The number of effects is sometimes limited by the boiling point of the liquor when it is concentrated to high density. It should also not be forgotten that in some cases the higher temperature which is absolutely necessary in multiple effects, will injure the liquor, which is especially the case with milk, malt extract, and others.

MATERIAL OF CONSTRUCTION

Evaporator bodies are generally built of cast iron, steel, or copper, and the tubes of cast iron, steel, charcoal-iron, copper, brass, or aluminium. This point should be considered very carefully as the material of construction will greatly influence the first cost of the equipment. Up to a few years ago, it was impossible to sell a cast iron machine for concentrating milk, or malt extract. Everybody used copper. At present, practically all evaporators handling these liquids are built of cast iron. The material of construction should be such that it will not be attacked by the liquor, but at the same time it should be of such nature that it will not spoil the product by forming mineral salts which will discolor the liquid. With the present prices of copper, it would be cheaper in some cases to use steel or wrought iron tubes, and replace them with copper as soon as it has reached the normal price again.

Lead-lined and copper-lined evaporators have not been satisfactory, but I understand that some machines, built of solid lead, have given good service. A few evaporators have been lined with acid-proof brick in order to prevent corrosion by organic acids, and the lining seems to have stood up quite well.

TYPE OF EVAPORATOR

As a general rule, horizontal tube evaporators with steam inside, and liquid outside the tubes are used for all solutions which do not precipitate solids during the boiling process. Vertical tube machines with the liquid inside, and steam around the tubes will handle solutions which are concentrated to a point where only crystals remain, or liquors which separate salts during the boiling process.

There are at present made in this country about a dozen different types of evaporators, and it is quite hard for the purchaser to select the type which is most suitable for his purpose. The most important point which should be considered in selecting the type and make of evaporator is the general efficiency with which the equipment will handle the liquid.

The efficiency of the evaporator will depend on the coal consumption, and the loss of liquor caused by entrainment and foaming.

The amount of steam used to evaporate a certain quantity of liquor will depend entirely on the number of effects, and has very little to do with the type of evaporator. One pound of steam will always produce in a single effect 1 lb. of vapor, less the loss by radiation, and loss by the reduced latent heat of the steam at low pressure. The loss by radiation can practically be eliminated by good covering of all parts of the equipment, and will be practically the same with all types of evaporators. The steam consumption of multiple effects will go down in proportion to the number of effects used. The quadruple effect will always produce with 1 lb. of steam, 4 lb. of vapor, less the losses given above, provided the temperature of the feed liquor is the same in all cases. I wish to call attention to the fact that the total steam consumption is very much influenced by the temperature of the feed liquor, and certain arrangements can be made in multiple effect evaporation to reduce to a considerable extent the amount of steam necessary for the heating of this weak liquor.

The efficiency will also be influenced by the losses caused by entrainment and foaming or frothing. Losses by entrainment can practically be eliminated by proper construction of the evaporator. It is due entirely to the high vapor speed above the liquor level. An evaporator which has too small a square area above the heating surface will always entrain when the heating surface is working at its normal capacity. So-called entrainment separators and catchalls will save some of this loss, but it is naturally better to construct the pan right from the start in such a way that no liquor will be entrained.

*A paper presented at the New York meeting of the American Chemical Society.

The foaming or frothing is due to physical properties of the liquor, and losses can readily be avoided with almost any type of evaporator by careful operation.

The steam consumption and therefore efficiency of the equipment will be somewhat influenced by the arrangement of the outlets and valves which remove the non-condensable gases, and water of condensation from the steam. If the vent valves are kept open too wide, steam will escape from the steam chest to the vapor body, and become a total loss.

Further points to be considered are the method of operation, and the simplicity of construction. Pumps should be eliminated as much as possible, as their upkeep is very expensive. Sometimes a special type of evaporator is necessary in cases where only a limited amount of space is available. Delicate liquor, especially of organic nature, should not be subjected to the heat for any length of time, and it is therefore necessary to choose a type of evaporator which only contains a small amount of liquor.

RELIABILITY AND EXPERIENCE OF MANUFACTURER

The workmanship and material to be used in the construction of evaporating equipments should be of the very best quality. The efficiency and capacity of a multiple-effect evaporator will be greatly reduced by leaks from the outside or from the steam chest to the vapor space. When cast iron is the material of construction, only a very close grain iron should be used. In case the evaporators are made of steel plate, the most stringent specifications and rules for boiler work are just good enough for the construction of evaporators. Especially in caustic work, rivets and seams should be made up with the utmost care, as it is almost impossible to repair a seam after once the caustic has gotten between the plates or into the rivet holes. It is therefore absolutely necessary that the manufacturer should be reliable, and have long experience in the manufacture of such equipments. It is desirable that the builder should have his own factory, or at least be able to control the construction of the machinery.

ACCESSORIES

The condensers, receivers, salt filters, pre-heaters, and all pumps should be amply large and of the very best quality, especially where twenty-four hours' service is contemplated. Pumps should not be operated normally with more than twenty strokes per minute, and wherever possible, arrangements should be made to seal the stuffing box of the piston rod.

GUARANTEE

Unless the purchaser has had considerable experience with the type of evaporator, and the liquor, it is always desirable to ask the manufacturer for certain guarantees covering:

Quantity of liquor to be handled per hour or twenty-four hours.

Quality of the finished product.

Total steam consumption, including pre-heating of the feed liquor.

Quantity of cooling water to be used for the condenser.

Such a guarantee will generally increase the price of the equipment, but it is an excellent safeguard against comebacks. These tests can be made at very little expense. In addition to this guarantee for capacity and efficiency, the manufacturer should give a complete guarantee for workmanship and material.

PRICE AND DELIVERY

Without any question, the price of the equipment is of great importance, but it should only be considered after all other points have been settled entirely satisfactorily. Quite frequently, a cheaper equipment will be very expensive to operate on account of the frequent repairs and replacements. The manufacturer should have a reasonable time for delivery, as evaporators are not carried in stock.

New York City.

Observations Upon the Atmospheric Corrosion of Commercial Sheet Iron*

Particularly in Regard to the Influence of Copper and Mill Scale

By E. A. Richardson and L. T. Richardson

The corrosion of iron and steel is a question that is becoming of increasingly great importance. The problem of finding the true nature of and the ultimate causes that underlie the rusting of iron is as yet unsolved. Much work has been done in the past, is being done at present and before the problem is solved, much more will undoubtedly be done in the future.

The paper will not burden itself with a lengthy review of previous work that has been done upon the subject, but will confine itself to a brief summary of such work.

As regards the relative merits of wrought iron and steel much work has been done, but observations on the two materials seem to be in poor agreement.

Of recent years the question of the rust-resisting properties of copper-bearing steels has arisen and remains as yet unsettled, the chief contenders being the makers of copper-bearing steel and those of pure iron. As far as numerical data are concerned, the advocates of copper-bearing steel seem to be in the lead; in fact it seems to the writers that one weakness in the argument of the pure iron advocates is that they give little numerical data to support their claims. To many, their arguments would carry much more weight if such data were included.

Briefly, up to about 1910, a considerable amount of work had been done upon the subject of copper in steel, but this work was mainly in the form of fragmentary observations on steels that contained small quantities of copper either accidentally or intentionally added, and a few actual tests upon copper-bearing material. Previous to this time there appeared to be no acute controversy as to the effect of copper in steel upon corrosion, although judging from the literature it did exist at this time to a rather mild extent as to the effect of this metal upon the physical properties of steel. The general impression, one would gain from reading these articles, is that copper in steel is a benefit as regards resistance to corrosion.

Shortly after 1910 copper-bearing steel was put upon the market as a corrosion-resisting material. The controversy then became acute, the chief objectors being the advocates of pure iron. The result has been that a considerable amount of work has been done and published without settling the question. Most of this work seems to have been done by those interested in copper-bearing steel in their efforts to prove that this material is the real rust-resisting material they claim it to be. A large share of the published work, which contains results from tests closely approaching actual service conditions, has been done by Mr. D. M. Buck[1]—a strong advocate of copper-bearing steel. The opposing side appears mostly in discussion of these and other

*A paper read at the New York meeting of the American Electrochemical Society.

[1] Buck, D. M. Copper in Steel—The Influence on Corrosion. Jour. of Ind. and Eng. Chem., June, 1913.

Buck, D. M., and Handy, J. O. Research on the Corrosion Resistance of Copper Steel. Jour. Ind. and Eng. Chem., March, 1916.

papers and appears to be taking a defensive stand. The impression, gained by the writers, from reading the available published evidence, is that copper-bearing steels do possess rust-resisting properties and are superior to any iron or steel now on the market.

Likewise, the influence of mill-scale upon the corrosion of iron is under discussion.

Friend[2] for instance states that "traces of oxides upon the surface of metals are powerful stimulators of corrosion."

A. Sang[3] says, "Black oxide only protects provided it is continuous and firmly anchored to the iron (Bower-Barffing, etc.); as mill-scale, which is loose and fissured, it is detrimental, the iron in contact with it and exposed rusts about 50 per cent faster."

Aston and Burgess[4] find "that mill-scale had an accelerating effect for an atmospheric test and a retarding action for a fume test." Further they state that "there is no doubt that the protective property of mill-scale is dependent upon its physical properties, continuity, etc."

G. C. Whipple and M. C. Whipple[5] tested steel, ingot iron and wrought iron with mill-scale and with mill-scale removed and obtained erratic results, but, generally speaking, the rusting was slightly greater in the case of the metals from which the mill-scale had been removed than in the case of the metals on which the mill-scale had been left. They state, however, "that the best remedy to protect steel from pitting is to remove mill-scale."

Buck and Handy[6] in their latest paper state "at the time of exposure of the full-sized corrugated sheets careful notes were taken concerning the physical appearance of the sheets as affected by the amount of mill-scale which was present, and as to whether they were outside or inside in the pack. During the progress of the test this feature was carefully watched, and the time of ultimate failure of sheets whose surfaces were comparatively free from mill-scale was compared with others of the same grade, whose surfaces were well covered with mill-scale. From these observations, we concluded that the influence of this original surface oxide is slight, and is lost in the early stages of rusting, for no difference in final failure could be noticed."

One thing, however, in regard to many tests that have been made upon the relative corrosion of iron and steel, is that insofar as the ultimate consumer is concerned, they are not of the greatest value, since many times only two or three materials were compared, or the materials were made especially for test and cannot be obtained in commercial quantities. Such tests do not carry the most weight since they do not have the air of disinterestedness that exists in the case of materials purchased upon the open market. In fact one of the arguments of the pure iron advocates is the objection to "special tests" and the demand for basing comparisons upon service tests only.

In view of the fact that no results had been published of a complete test on commercial materials, it was deemed desirable to make a test containing all the types of iron and steel that could be obtained.

Some of the kinds of materials that are commonly used for structures, exposed to atmospheric corrosion, are:

1. Steel.
2. Puddled Iron.
3. Commercially Pure Iron.
4. Copper-Bearing Steel.
5. Cast Iron.

This paper deals with the first four classes.

Accordingly there were obtained upon the open market the following materials in the form of black sheets of 26 gage:

1. Bessemer Steel.
2. Open Hearth Steel.
3. Charcoal Iron.
4. Commercially Pure Iron.
5. Commercially Pure Iron.
6. Copper-Bearing Iron.
7. Copper-Bearing Steel.
8. Copper-Bearing Bessemer Steel.
9. Copper-Bearing Open-Hearth Steel.

These materials analyzed as follows:

	Copper	Manganese	Carbon	Phosphorus	Sulphur	Silicon
1	Trace	0.300	0.01	0.087	0.054	......
2	Trace	0.413	0.01	0.079	0.041	......
3	0.044	0.031	0.01	0.050	0.024	0.020
4	0.016	0.028	0.01	0.009	0.025	......
5	0.028	0.009	0.01	0.006	0.024	......
6	0.237	0.006	0.01	0.004	0.054	......
7	0.181	0.100	0.01	0.003	0.0[illegible]7	......
8	0.256	0.315	0.08	0.092	0.046	......
9	0.268	0.387	0.01	0.052	0.024	......

Before starting a work of this character, which involved quite some labor, due consideration was given to the methods of testing and in particular to those methods about which there is some difference of opinion. Questions arose concerning the desirability of a previous heat treatment and the necessity and means of removing mill-scale previous to testing.

Opinions differ as to whether samples of iron should be tested just as received or whether all test-pieces should receive some treatment so that the physical properties will be as nearly identical as possible. One author contends that samples should be tested as purchased, since the material that the samples represent will be used just as purchased. On the other hand, there are those who contend that all samples tested should have as nearly the same treatment as possible, in order to eliminate as many of the variables as possible. They suggest, therefore, that the test-pieces be annealed at the same temperature and that mill-scale be removed.

It would seem that the method used for testing should depend upon the results to which the data is to be put. If the results are intended for the ultimate consumer the material should be tested just as purchased since this is the condition that it is used by the ultimate consumer. On the other hand, if the data is for scientific purposes such as determining the effects of various elements in the material, all variables other than the ones under investigation should be removed if it is possible to do so.

However, to make the work as broad and as complete as possible, it was decided not to limit the test to one method, but to try out both ways and to determine the relationship between the two.

Since part of the specimens were to have the mill scale removed, the question arose as to what method should be used for removing this scale. In previous published work, very little has been said about the method of cleaning test specimens. When stated, however, it has usually been done by mechanical means such as filing or grinding, or by chemical means such as acids. Experiments were, therefore, conducted on the effects of methods of removing mill-scale upon the sub-

[2] Friend, J. N. The Corrosion of Iron and Steel, p. 251.

[3] Sang, A. The Corrosion of Iron and Steel, p. 81.

[4] Aston, James, and Burgess, C. F. The Rate of Rusting of Iron and Steel. Eighth Int. Congress of Applied Chem., 26, 453.

[5] Whipple, G. C., and Whipple, M. C. Mill-Scale as a Cause of Corrosion. Eighth Int. Congress of Applied Chem.

[6] Buck, D. M., and Handy, J. O. Research on the Corrosion Resistance of Copper Steel. Jour. Ind. and Eng. Chem., March, 1916.

sequent corrosion. The results of these experiments have already been published.[7] It was shown in this paper that methods of cleaning by the use of chemicals had a profound effect upon the rate of corrosion, especially on tests of short duration.

In the contemplated test a clean iron surface was necessary in which the surface iron was in the same physical and chemical state as the iron beneath the surface. It was, therefore, decided that removal of the mill scale by pickling in sulphuric acid, thorough washing with water and drying and subsequent removal of the surface iron with fine emery cloth would give a surface that was identical with the material itself.

The question also arose as to the method by which corrosion was to be estimated. There is a choice of methods to determine the rate of corrosion. One method commonly used is to determine the loss in weight after exposure for a given length of time and considering this loss as an index of corrosion. Another method is to allow the test specimens to corrode until failure occurs and to take the length of time as an index of corrosion. Inasmuch as there is some question as to the reliability of the "loss in weight" method, it was thought best to continue the test to the failure of the specimens.

This made it necessary to decide upon some standard condition at which failure could be considered to have taken place. Evidently, failure should not be taken at a point when the iron has completely rusted away or even when it has almost disintegrated, since any sheet iron in service would be of no value long before such a condition obtained. The point of failure selected was when the sheet iron was in such a condition that it could be seen to be perforated when the rust was removed by gentle tapping with a blunt object such as a file or nail. By using one specimen of each kind of material as a test piece that was tapped and examined at intervals of about two weeks, a close approximation to the time of failure could be obtained. Thus the other specimens were not molested until the latter part of their useful life and the effects of tapping were practically eliminated from the results. By this method, it is believed that the life of each material was obtained to within an error of three or four weeks.

The sheets of 26-gage iron were accordingly prepared for test by cutting into pieces 5 in. x 8 in. (12.7 cm. x 20.3 cm.). For the test on the material as received ten pieces of each kind of iron, that were found by measurement to be of standard thickness, were used. For the test on the prepared material, a number of pieces of each material were annealed at a red heat and then cleaned by the method already described. Great care was taken to give all of these test pieces exactly the same treatment. Ten of the prepared specimens of each material that were found by measurement to be of the same thickness were taken for test. These prepared pieces were of practically the same thickness as the "as received" samples tested, due, no doubt, to the extreme thinness of the mill-scale.

On account of the precautions taken as regards uniform thickness of materials, the method of estimating failure and the method of cleaning surface, it is believed that the tests should be comparative.

All samples were then placed securely in a wooden rack and exposed to the weather May 24, 1914. The atmosphere was what might be described as a semi-country one, and cannot be taken as an atmospheric acid test.

At the very start a marked difference was noted in the character of the rust formed on different materials. Whereas, on the Bessemer and open-hearth steel samples, the rust was of a yellowish-red color and became loose rapidly, the rust on the others was dark red in color and much more adherent. This adherent

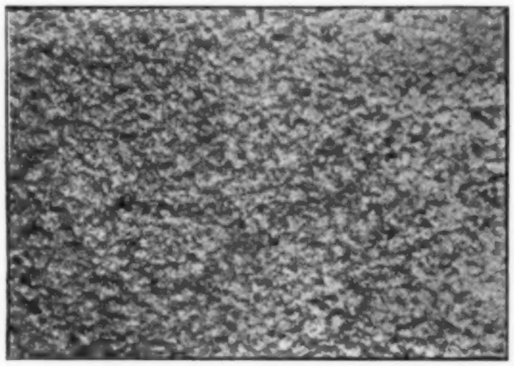


FIG. 1—RUST ON BESSEMER AND OPEN-HEARTH STEEL

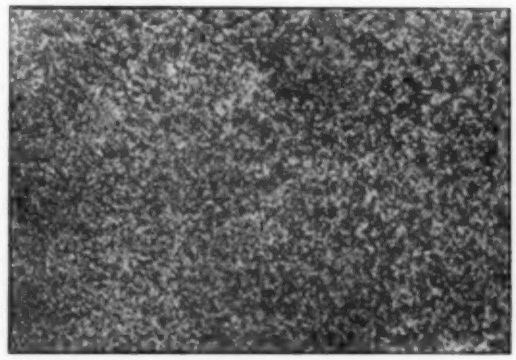


FIG. 2—RUST ON CHARCOAL IRON

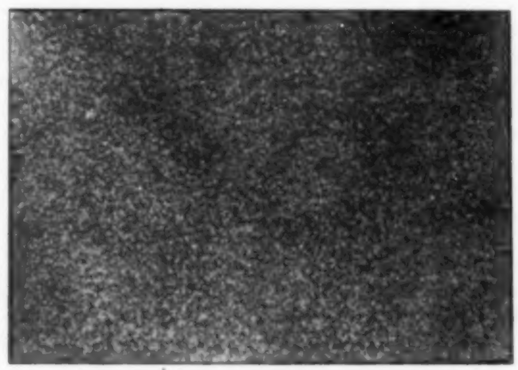


FIG. 3—RUST ON COPPER-BEARING STEEL

state seemed to reach its maximum in the copper steels, where the rust was very dark and fine grained. Fig. 1, Fig. 2 and Fig. 3 represent photographs taken about one year after the test was started and conveys in a rather poor way the character of the rust. Fig. 1 is characteristic of Bessemer and open-hearth steel. Fig. 2 is characteristic of charcoal iron, of commercially pure iron and iron containing copper, and Fig. 3 is characteristic of copper-bearing steels.

From visual observations at this time there appeared to be little difference between pure irons with or without additions of copper.

The life of the different materials tested is given below; each figure being an average of ten test pieces and represents the time for failure in days:

[7] Richardson, E. A. The Effect of Pickling on the Corrosion of Iron. Met. and Chem. Eng., 12, 759.

At the present writing the three samples of copper-bearing steel are still in good condition. The rust is still adherent and the underlying metal is still intact. The life of these steels has been estimated at 1200 days, which figure the writers believe is very conservative. These specimens are still exposed to the weather and will be until failure occurs.

	Material as Received	Material Annealed and Surface Cleaned
1	348	363
2	367	361
3	615	558
4	508	437
5	675	467
6	743	601
7, 8, 9	1200 (estimated)	1200 (estimated)

Conclusions. Taken as a whole, the results indicate that copper-bearing steels are, without doubt, decidedly superior to any of the other materials tested. The remaining materials may be divided roughly into two classes, one class including the ordinary steels (Bessemer and open-hearth) and the other class, the commercially pure irons and the copper-bearing irons. Charcoal iron is classed with the pure irons. We have obtained results in another test which would indicate that the resistance of wrought iron to corrosion is due to the purity of its iron and not to slag inclusions. In addition, it was noted during the present test that charcoal iron appeared to corrode in very much the same way as pure iron.

In regard to the steel-iron question it is noted that the pure irons (including charcoal iron) are superior to steel. It is believed that this superiority is due to the purity of the iron, or to some combined effect of manganese and copper.

The results obtained in regard to the effects of mill-scale do not agree with the results obtained by others. They indicate that with steels which rust rapidly, mill-scale is a stimulator of corrosion. On the other materials tested, the mill-scale has exerted a protective action. We have no explanation for this.

The important feature of the results, however, is that it substantiates the claim made in several other publications that the addition of copper to steel in amounts of about 0.25 per cent causes a remarkable increase in its ability to resist atmospheric corrosion. In the present test, the addition of about 0.25 per cent copper to Bessemer or open-hearth steel has resulted in an increased resistance of 300 or 400 per cent.

The addition of copper to pure iron also results in an increased resistance to corrosion, but to no such an extent as the addition of a similar amount to steel. The addition of about 0.25 per cent copper to a commercially pure iron results in the useful life being increased by about 20 per cent. This figure was arrived at by comparing the average life of irons Nos. 3, 4 and 5 with No. 6.

We have been unable to determine the reason for this effect of copper in reducing corrosion. It is believed, in view of the fact that the copper exerts a greater influence in steel than in iron, that it must be due to the combined presence of copper and manganese, since the chief difference in the iron and steels under consideration is in the manganese content. It may be that the copper eliminates a harmful effect of manganese, or it may be that it is some combined effect of these two elements that acts as a protection to iron. The writers are inclined to believe that it is the latter cause.

This conclusion, the writers believe, is also confirmed by the results of other observers. Mr. D. M. Buck[8] tested several kinds of sheet irons and steel by exposing pieces 2 in. x 4 in. (5.08 cm. x 10.16 cm.), 27 gage, to the atmosphere in a mill yard at McKeesport, Pa., and found the loss in weight after eleven months to be as follows:

No.	C.	Mn.	S.	P.	Si.	Cu.	Loss*	Condition of Test-Pieces After Exposure
E	.04	.30	.043	.065	....	.31	2.65	No holes.
V	.04	.39	.078	.114	....	.31	2.75	No holes.
Z	.04	.43	.049	.099	.011	.25	2.83	No holes.
D	.06	.50	.037	.016	....	.26	2.94	No holes.
C	.06	.33	.035	.018	....	.25	2.96	No holes.
H	.042	.16	.024	.003	....	.21	3.05	Few holes in 2 pieces.
O	.027	.07	.033	.007	....	.09	3.31	Few holes in 4 pieces.
W	.049	.05	.043	.005	....	.10	3.72	Many holes in all pieces.
J	.022	.03	.031	.006	....	.034	4.17	Many holes in all pieces.
I	.03	.06	.013	.052	.039	.07	4.26	Many holes in all pieces.
Y	.04	.45	.046	.099	.006	Trace	6.94	Only a lace work of steel left.

*Loss given in oz. per sq. ft.

Similar results were obtained upon tests made at Scottdale, Pa., and in McKeesport city water. These tests indicate that copper even up to 0.10 per cent added to low manganese materials increases their resistance to corrosion but little. Ordinary steels containing about 0.40 per cent manganese, but no copper, are very poor as regards resistance to corrosion but additions of copper to such steels result in a greatly increased resistance. A maximum resistance is reached with about 0.25 per cent copper. These results were also confirmed upon full-sized sheets of the same materials and in the above cited papers several excellent photographs are given.

The writers believe, in view of these results, that the resistance of pure iron to corrosion could be increased by the addition of both manganese and copper, and that additions of manganese to pure iron or steel, even up to 3 or 4 per cent, or more, with a corresponding increase in copper to produce a maximum effect should give a material more resistant to atmospheric corrosion than the copper steel now on the market.

Also, some interesting results might be obtained by substituting for manganese in copper-bearing steels or irons, chromium, vanadium, tungsten, or molybdenum.

SUMMARY

1. Copper-bearing steels are decidedly superior to pure iron, steel, or charcoal iron.
2. The addition of copper to pure iron increases its resistance to corrosion, but to no such an extent as similar additions to steel.
3. Charcoal iron and pure iron are superior to steels as regards resistance to atmospheric corrosion.
4. Charcoal iron is very similar to pure iron in its resistance to corrosion.
5. Copper is believed to decrease corrosion due to some mutual influence of manganese and copper.
6. The additions of larger amounts of manganese and copper to pure iron or steel are suggested as well as additions of copper-chromium, copper-vanadium, copper-tungsten, or copper-molybdenum.
7. Mill-scale stimulates corrosion in rapidly rusting materials and retards it in slowly rusting materials.

[8]Buck, D. M. Recent Progress in Corrosion Resistance. Amer. Iron and Steel Inst., May, 1915.
Also pamphlet. Keystone Copper-Bearing Steel. American Sheet & Tin Plate Company.

Foreign Trade.—At the third annual meeting of the National Foreign Trade Council held recently at the Hotel Biltmore, New York, it was the consensus of opinion that in order to meet the world's economic conditions following the war, combinations of exporters must be legalized, the tariff system must have greater elasticity, the merchant marine must be developed and special education must be provided.

High Temperature Heat Developed During Electrolysis*

By Carl Hering

When the current density on a cathode immersed in certain aqueous electrolytes, is increased sufficiently, the cathode becomes red hot and may even melt. Steel can thus be melted electrically while immersed in an aqueous solution.

The purpose of the present notes is to describe briefly some of the properties of this phenomenon and to give some quantitative data obtained from tests. These tests were made only for a preliminary study of these properties and the quantitative data are therefore only crudely approximate.

The explanation of the phenomenon is that with such high current densities the volume of gas formed around the cathode so diminishes the cross section of the conducting liquid between the bubbles that the so-called pinch effect severs what is left of the liquid conductor and keeps it severed by breaking it instantly wherever the liquid and electrode tend to unite again. The film of gas thus formed around the cathode either has an extremely high resistivity, such that the current passing through it develops much heat, or else something of the nature of an arc forms in this film, the difference being that in the latter case there is a transferrence of material through the current path, while in the former there is none; the indications are that the passage of the current through this film is of the nature of an arc. In some respects this film is like that formed in the so-called spheroidal state, when water is dropped on a red-hot plate.

The electrolyte must be one which will develop a free gas at the cathode at these high current densities, which almost any aqueous solution will do. The impressed voltage must of course be high enough to force the current through this film, from 65 to 115 volts in these tests.

The present tests were made with current from a lighting circuit of 123 volts using a bank of lamps in series with the cell. Small strips of thin sheet iron were used as cathodes; the anode was lead, and the solution sulphuric acid of about 1.2 specific gravity. The current through the cell, the voltage at its terminals, and the surface immersed (counting both sides) were measured. Owing to the meniscus and the violent ebullition this surface could be measured only approximately, and as it was small the error due to the three edges and two corners may have been relatively large, as in electrolysis the equivalent of an edge and a corner in terms of a surface, is an unknown factor.

When, with a limited current, a cathode is first immersed deeply so that the usual gasing in the cold state takes place, and is then gradually withdrawn to reduce the submerged surface, a point will be reached when a very sudden change takes place; the current will fall greatly, the voltage will rise greatly, there will be a hissing noise, and the cathode will instantly become red hot, at times melting into globules. The liquid surrounding it also looks red, having the delusive appearance of also being red hot.

If, while thus red hot, the electrode is lowered again very slowly, this high temperature state can be maintained for considerably greater immersions than that at which it started during withdrawal.

By then continuing to lower it, a state is reached without much change in the current or voltage (the current rises and the voltage falls), in which the cathode ceases to be red hot but is enveloped in a distinctly blue film and the hissing is louder. With a still further immersion the conditions change very suddenly again to that of ordinary electrolysis, the current increasing and the voltage dropping, both very greatly. This change occurs when the film breaks and the surface is again wetted by the liquid.

Hence to produce this phenomenon, under the conditions of this test, the cathode must be immersed slowly, only as fast as it becomes heated; the moment the film becomes broken by the surface becoming wetted, the phenomenon ceases. With sufficiently high current densities it will break into this hot state immediately on the closing of the circuit, even when the cathode has previously been immersed.

As the cathodic gas is presumably hydrogen, it was thought that the iron cathode would remain clean and bright. Quite the contrary, however, a thick, black, brittle material forms on it in molten globules, which no doubt is the black oxide, as it is dissolved readily by the current when the film is broken and ordinary electrolysis takes place. The oxygen of this oxide seems to have come from the water, being presumably carried across the film by the arc. Unless this rapid formation of oxide can be prevented, the use of this method for tempering steel objects superficially by opening the circuit after the surface has been heated and while still submerged, would probably not be practicable.

The following data will give a rough idea of the quantitative relations. At about 10 amp. per square centimeter (9290 amp. per square foot) the sudden break from the cold state to the hot state tends to begin, at least under the conditions of this test. The energy at the surface of the cathode before the break, was then being developed at the rate of about 100 watts per square centimeter (93 kw. per square foot), much of which was chemical energy.

When the break occurred the current fell abruptly to about a fifth and the voltage rose more than tenfold. The current density therefore then becomes much smaller, but the surface energy becomes very much greater.

When the current density after the break is about 3.5 amp. per square centimeter (about 3250 amp. per square foot) the break always occurs, even when the circuit is closed after the cathode is immersed, hence it was not possible to measure it before the break occurred. The surface energy was then being developed at the rate of over 400 watts per square centimeter (about 370 kw. per square foot), which is presumably a far higher heating rate than is developed by a blast flame directed on to a surface.

The following figures will give some idea of what this high rate of heat development means. It is equal to 350 B.t.u., or 78.5 kg. calories, per second per square foot. If a kilowatt-hour will melt about 7 lb. of steel, this energy would melt about ¾ lb. of steel per second over a surface of 1 sq. ft., and it is likely that most of this film heat goes into the metal and less of it into the water on account of the very high surface resistance of water. The usual steam boiler practice of evaporating 3 lb. of water per hour per square foot of heating surface, is equivalent to a flow of energy through the walls of the tubes, of about 0.85 kw. per square foot; hence 370 kw. represent a rate of surface heating about 440 times as great as that in ordinary boiler practice.

During the next state when the cathode becomes cooler and is enclosed in a blue hissing envelope, the current density was about 4 amp. per square centimeter (about 3700 amp. per square foot) and the energy de-

*A paper read at the New York Meeting of the American Electrochemical Society.

velopment at the surface was about 270 watts per square centimeter (about 250 kw. per square foot) showing that the current density was then a little higher than during the red hot state, but the surface energy development was considerably less, hence the cathode was cooler.

When the current density during the latter state is then still further reduced by deeper immersion, to about 2 to 2.5 amp. per square centimeter (about 1900 to 2300 amp. per square foot) and the surface energy to about 130 watts per square centimeter (about 120 kw. per square foot) and the surface energy to about 130 watts per square centimeter (about 120 kw. per square foot), the film breaks, the cathode becomes wetted and ordinary gasing in the cold state sets in. Hence roughly about 100 kw. per square foot is the breaking point either way. Being caused by the pinch effect, current densities may not be the criterion in this phenomenon.

A rough test was then made in which the electrode to be heated was made the anode. Only by barely touching the liquid with the anode could any high temperature effects be produced, and even then only the corners became visibly red; with a further immersion the film always broke. The voltage before the break was about 117, very nearly the maximum available, and even this gave less than half an ampere; with a higher voltage better results could no doubt be obtained. The current density was, as nearly as could be estimated, about 4 amp. per square centimeter, hence about like that with the cathode, but the energy development was over 450 watts per square centimeter, hence higher than with the cathode. This may be due to the fact that only half as much gas is developed per ampere at the anode than at the cathode, or if an arc is formed through this film it may mean that the current traverses the arc more easily from liquid to electrode than from electrode to liquid.

The metal of this anode was eaten away slightly at the edge and was coated with a red layer, presumably the lower oxide, though sometimes it was left gray and bright. It did not seem to be dissolved however as fast as would be expected.

The curious fact that the cathode apparently becomes very strongly oxidized when thus heated, interferes with using this method for the surface hardening of steel objects; but with higher voltages it might be possible to heat so rapidly, perhaps in a few seconds, that the oxidation during that brief time might not be serious.

As this method enables one to heat a surface far more rapidly than it can be done by means of a flame, it may become possible to heat a surface to a high temperature so quickly that the heat would not penetrate into the interior until after the object of the heating has been accomplished, as for instance in alloying a surface with a metal which has been plated upon it. The heat is also more evenly distributed over a complicated surface than is possible with a flame, and the temperature is not limited like in combustion heat.

If it should be true that the passage of the current through this film forms a true arc, then it would seem to follow that the true electrolytic action takes place on the liquid side of the film, which would mean that the real cathode then is the film of hot gases and not the metal. The conditions would then be similar to when an arc is struck between a carbon rod and the upper surface of an electrolyte, in which the question also arises what the real electrode is at which the electrolysis takes place. Unipolar electrolysis would be contrary to our present conceptions.

Philadelphia, Pa.

History of the Flotation Process of Inspiration*

By Rudolf Gahl, Ph.D.

Metallurgist in Charge of Concentrator, Inspiration Consolidated Copper Co.

(*Concluded from page 405*)

Operation of Large Concentrator

FLOW SHEET OF CALLOW SECTIONS

The first four sections of the commercial concentrator of the Inspiration Company were equipped with Callow flotation machines. The flow sheet followed in these sections is illustrated in Fig. 19. As will be seen from this illustration, the ore, after having been reduced to the desired fineness, and having been oiled in the Marcy ball mills, is sent to twelve (in other sections eight) Callow cells. The tailings from these primary cells are sent to a drag classifier designed by

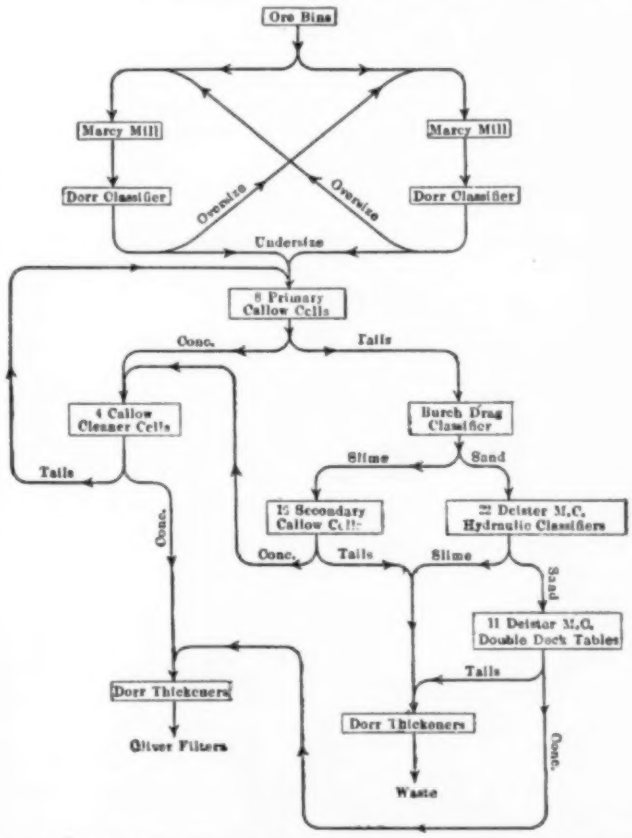


FIG. 19—FLOW SHEET OF INSPIRATION CONCENTRATOR SECTIONS EQUIPPED WITH CALLOW FLOTATION MACHINES

Mr. Burch, which effects a separation of sand and slime. The slime is retreated in twelve (in other sections sixteen) additional Callow cells, while the sand is sent to a hydraulic classifier and then to tables. The concentrates made both on the primary and the secondary Callow cells are retreated in a group of four Callow cleaning cells from which the tailings are returned to the head of the primary Callow cells. On the tables of the Deister Machine Company a separation is made between concentrates and tailings, but no middlings are produced and no part of them is reground. This, however, is probably only a temporary arrangement, the idea being that a suitable regrinding and reconcentration process will be installed later, after having been worked out by extensive tests.

FLOW SHEET OF INSPIRATION SECTIONS

Thirteen sections of the Inspiration concentrator are equipped with Inspiration flotation machines. The flow

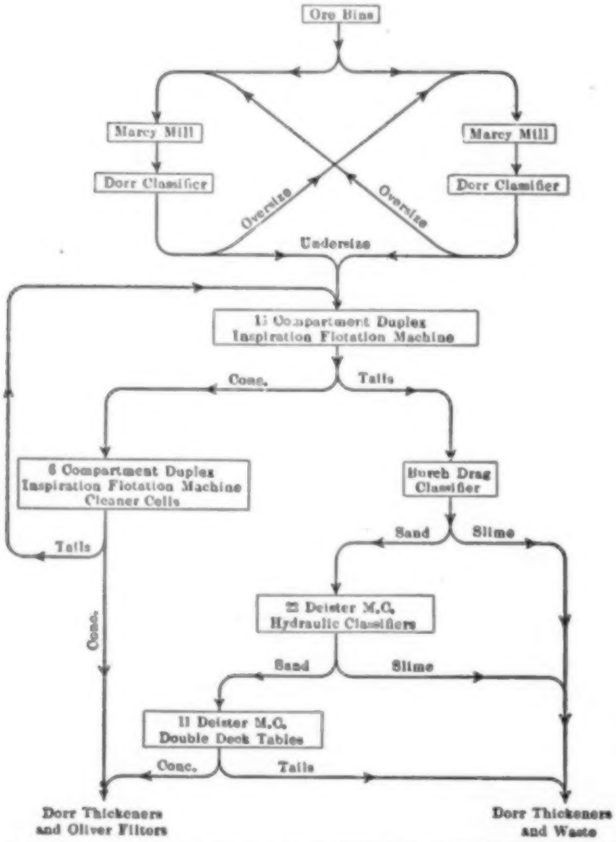


FIG. 20—FLOW SHEETS OF INSPIRATION CONCENTRATOR SECTIONS EQUIPPED WITH INSPIRATION FLOTATION MACHINES

sheet of these sections is represented in Fig. 20. The ore, after having been crushed and oiled, passes to the head of the flotation machines and traverses their whole length. The resulting tailings are split by the same kind of a drag as mentioned before, into a sand and slime product. The slime product is run to waste. This is thought permissible because, after having passed through the whole length of the flotation machine, the slime has been impoverished to such an extent that retreatment seems unnecessary. The sand product undergoes the same retreatment as that described for Callow sections.

INSPIRATION FLOTATION MACHINE OF STEEL CONSTRUCTION

Fig. 21 shows the drawing of an Inspiration flotation machine of steel construction as designed by Mr. Burch's office. At the end of each section of eight compartments, a pulp overflow is provided which regulates the level of the pulp in the preceding compartments of the flotation machine. The subdivision into two sections of eight is made in the interest of closer regulation of the pulp levels. It had been feared that if no such subdivisions were made, and the regulation of the levels accomplished at the tail end only, appreciable fluctuations might take place in the compartments near the feed end due to changes in the volume of pulp treated, and might prove highly undesirable.

One point in the construction of the Inspiration flotation machines in which we take considerable pride, is the method in which the air is introduced. The machines have solid bottoms; all pipe connections are made from above and are at all times visible. The porous bottom rests on top of the regular bottom of the machine and is introduced from above. It is illustrated in Fig. 22. As will be seen, it consists of a lower air chamber having partitions running lengthwise, which, however, do not extend down to the bottom of the air chamber and, for this reason, do not

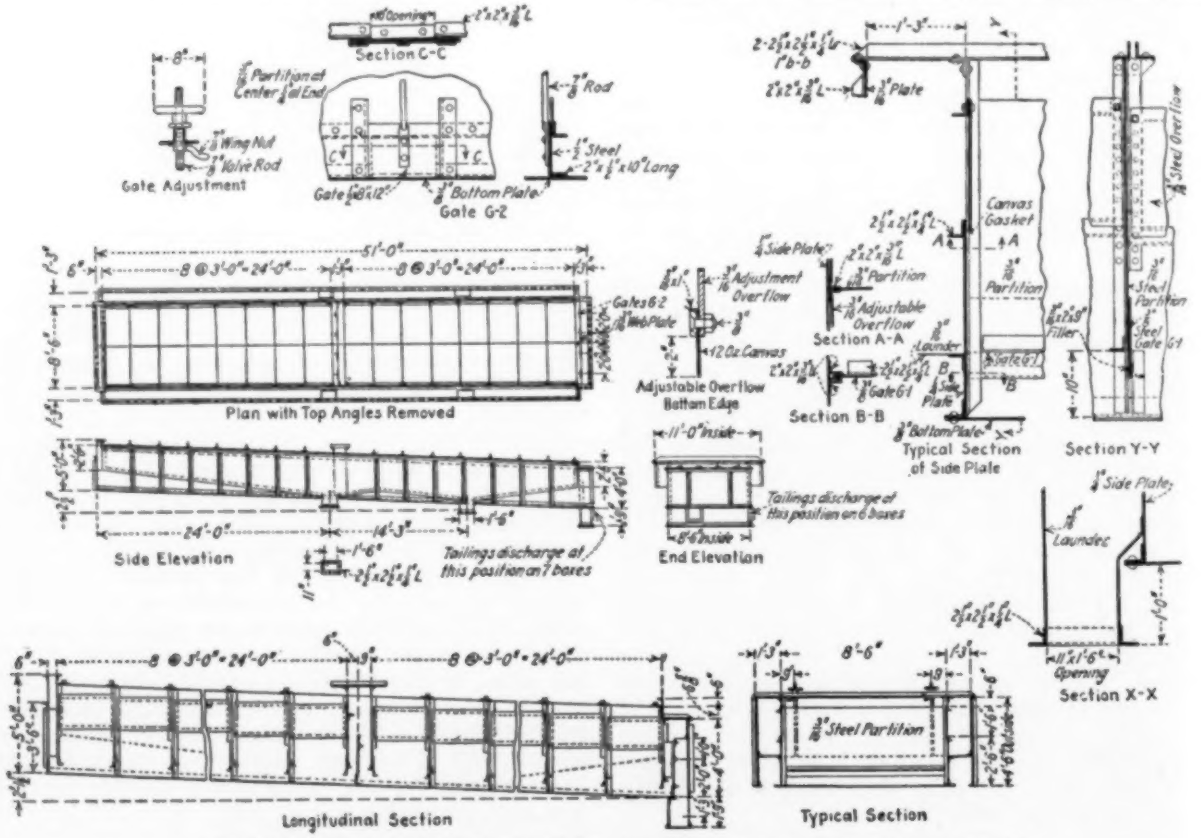


FIG. 21—INSPIRATION FLOTATION ROUGHER CELLS OF STEEL CONSTRUCTION

interfere with the interchange of air between the narrow compartments thus formed. A grate, which forms the upper part of the porous bottom can be fastened to the lower part by a number of bolts. Before putting them together, a porous medium (for instance, canvas) is placed between the two pieces. The air enters through a pipe from the top which screws into the lower casting. Arrangements are made, of course, to secure an air-tight joint where the pipe passes through the porous medium. When assembled, the bars of the upper grate form channels in the lengthwise direction of the machine. The bars are the only parts that protrude above the canvas and, on account of their arrangement longitudinally, they do not interfere with the passage of pulp through the machine.

The cleaner cells consist of six compartments in series. Both rougher and cleaner cells are divided by a partition in the middle, running the whole length of the machine. The operator is therefore enabled to throw all the feed on one side of the machine when desired, thus permitting repairs to be made on the compartments of the other side whenever necessary.

In the beginning it had been supposed that throwing all the feed on one side of the flotation machine might seriously overload that side, and for this reason, in the first sections installed, provisions were made to permit removing and replacing the porous bottom from any one compartment without interrupting the flow of pulp. As far as lifting out the bottom is concerned, this, of course, can be done in any case, but while one of the bottoms is withdrawn sand will pile up to a certain extent in the middle of the compartment. To remove this sand before returning the porous bottom, a system of perforated water pipes was installed under the air chamber. They allow the washing out of the bottom of the machine by the application of water pressure.

MINERALS SEPARATION SECTION

One section of the concentrator is equipped with machines of the Minerals Separation Company, Hebbard type. The flow sheet, as illustrated in Fig. 23, is practically the same as the one shown in the Inspiration sections. The only difference is that two cleaner cells in parallel are used in place of the one cleaner cell of the Inspiration type. The drawings of the machine are reproduced in Fig. 9.

FILTER PLANT

It is necessary to reduce the ore to a certain fineness before the mineral contents of the feed can be treated by flotation, and as fine concentrates have the characteristic of retaining water with greater tenacity than coarse concentrates, a filter plant is a necessary adjunct of a flotation plant.

In the Inspiration mill both the flotation and table concentrates are sent to Dorr thickening tanks, five of them being 60 ft. in diameter and three of them 80 ft., representing a total area of about 29,217 sq. ft., or, as the daily production of concentrates amounts to about 600 tons, a settling area of around 48.7 sq. ft. per ton of concentrate sent to the settling tanks. The settling tanks are each provided with a double ring of high baffle boards to prevent the foam that forms on the top from contaminating the overflow. The settling used to be carried out in two steps, some of the tanks serving as preliminary settling tanks, whiie others resettled the overflow from the preliminary tanks. At present we operate all the concentrate settling tanks in parallel.

The spigot discharges feed six Oliver filters. The ratio of solids to water is about 1.65 to 1 at this point. The filters reduce the concentrate moisture to an average of about 17 per cent of the wet pulp. This figure varies, however, within rather wide limits from day to day. The moisture contents of the concentrate seem to depend in the first place on the percentage of insoluble material contained in the concentrates, as will be seen from the graphic representation of the relation between the two things in Fig. 24. It will be noted that a rise in the percentage of insoluble matter gen-

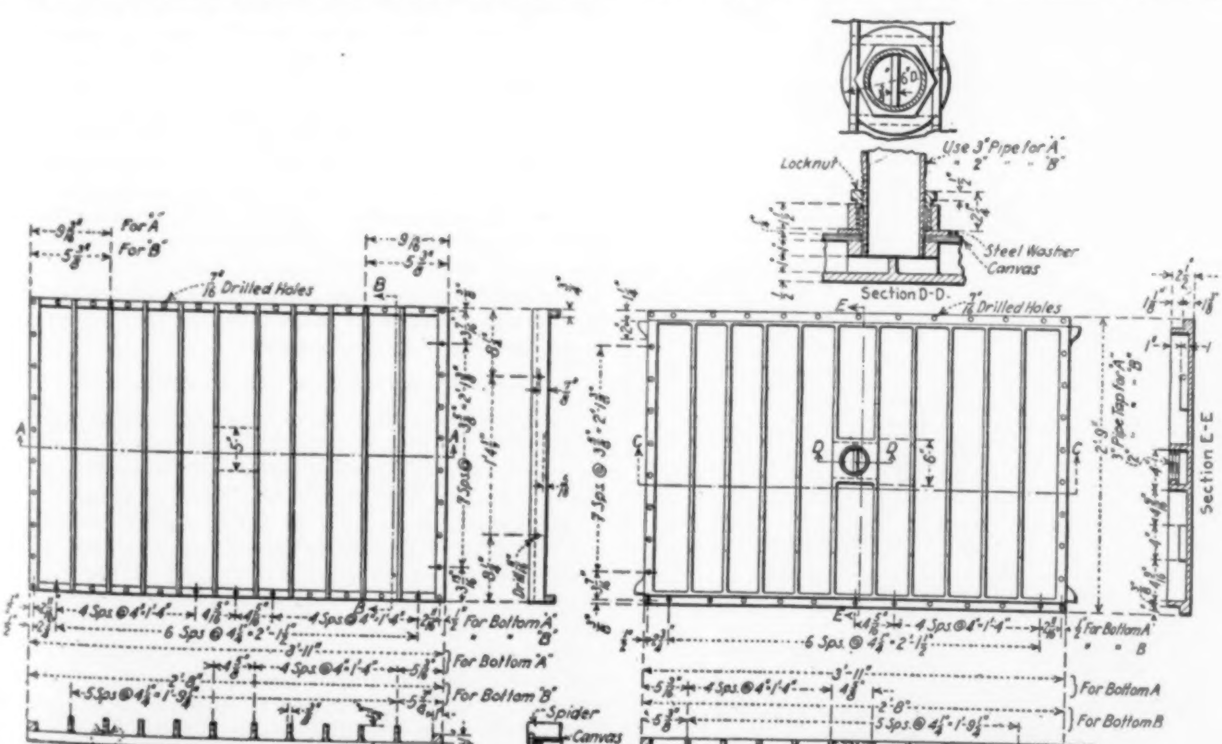


FIG. 22—INSPIRATION FLOTATION MACHINE BOTTOMS

erally corresponds to a rise in the concentrate moisture and *vice versa*. A moisture of 17 per cent is, of course, in excess of what seems desirable in view of the fact that the smelter penalizes water contained in the concentrates.

For this reason several attempts have been made to reduce the moisture. The first plan followed was to inject steam into the filter tank, with the object of heating the pulp. An appreciable increase in the capacity resulted from this, while no marked reduction of the moisture contents took place. The same effect was obtained by the addition of slaked lime, which we tried lately in our Oliver filters. It shows itself very readily in the formation of a thicker filter cake, thus causing a larger output of the filters. We have, however, not been able to effect a reduction in moisture by the use of lime. We have adopted the addition of lime to the filter pulp in regular operation on account of its decided benefit as far as the capacity is concerned. As a rule five filters can handle the whole output of the concentrator; that is, each 12 x 12-ft. Oliver filter has a capacity of about 120 tons in 24 hr.

Results Obtained in Commercial Concentrator

On account of the fact that the concentrator operated by the Inspiration company has only just left the stage of construction, it is not possible to give results obtained in the operation of it as a whole. As, however, an interval of several months has elapsed between the starting of the first and the 18th section, we are in a position to give at least preliminary results derived in actual operation on a fairly large scale.

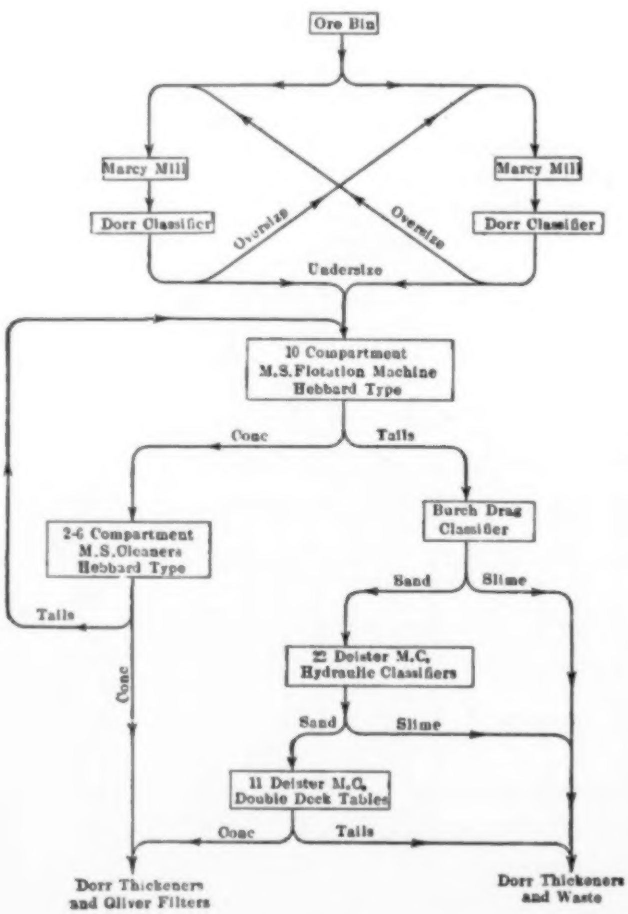


FIG. 23—FLOW SHEET OF INSPIRATION CONCENTRATOR SECTION EQUIPPED WITH MINERALS SEPARATION FLOTATION MACHINE

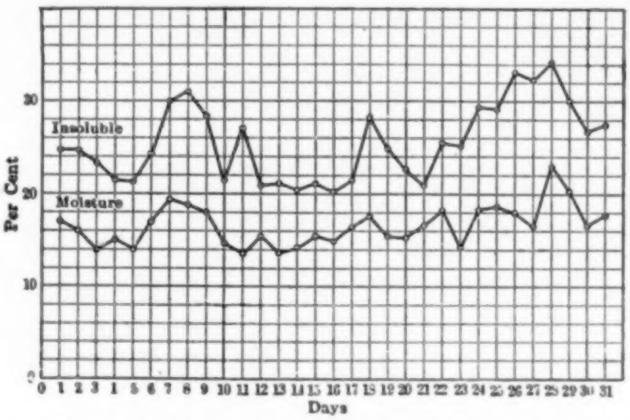


FIG. 24—CURVES SHOWING RELATION BETWEEN MOISTURE CONTENTS AND INSOLUBLE MATTER IN CONCENTRATES, OCTOBER, 1915

TONNAGE

Each of the sections of the Inspiration concentrator has a rated capacity of 800 tons; at present most of the sections exceed 900 tons actual capacity. Ordinarily, this tonnage is treated on one Standard duplex Inspiration machine consisting of sixteen double compartments, while the concentrates are cleaned on a cleaner cell with six double compartments. The size of the roughing compartments is 3 ft. by 4 ft. 3 in.; the size of the cleaner compartments is 3 ft. by 3 ft. Accordingly, the total area of combined rougher and cleaner cells is 492 sq. ft. Assuming the tonnage handled to be 800 tons, this makes a tonnage treated of 1.62 tons per day per square foot of surface. In the course of construction the erection of flotation machines did not always keep pace with the erection of the grinding mills. For this and other reasons it has frequently been necessary to combine the product from the two grinding sections in one flotation section; in other words, to throw an overload of 100 per cent on the flotation machines. Our experience is that overloading the machines by 100 per cent, or raising the tonnage to 3.24 tons per square foot of surface, does not increase the tailing losses very materially.

It follows, therefore, that the machines handle an overload without serious additional copper loss, and it has been our experience that there is no mechanical trouble whatever connected with overloading the flotation machines to such an extent. We have also had to resort to overloading the Callow cells, and have likewise found that the recovery does not fall off seriously.

For the Minerals Separation machine of the Hebbard type, which is installed in our section No. 10, we have no figures of a similar character.

AIR AND POWER CONSUMPTION

We have found that three blowers, of a capacity of 8000 cu. ft. per minute each, are sufficient to supply air for six sections of flotation machines. Accordingly, one section requires 4000 cu. ft. of air per minute. As the flotation machines in an Inspiration section have a surface of 492 sq. ft., it follows that the air consumption per square foot of porous surface is 11.8 cu. ft. per minute; the maximum pressure required is $4\frac{1}{2}$ lb. at the blowers and practically the same at the flotation machines, as there is no serious loss of pressure in the air-conduits. The power consumed for furnishing air has been determined carefully by wattmeter readings of the motors furnishing power for the blowers. The actual power consumed is 87.5 kw. per section; or, figuring again with the rated section capacity of 800 tons, 2.63 kw.-hr. per ton of ore treated. We have not been able to make

separate tests for the Callow and Inspiration sections, but assume that the air consumption is approximately the same in both. We have no figures yet for the Hebbard type machine. To get the total amount of power consumed in connection with the flotation machines, a small amount of power, probably around 10 kw. or 0.30 kw.-hr. per ton of ore, has to be added to the power consumed for the production of air on account of the fact that the cleaner tailings are pumped back to the rougher cells and retreated, and that in the Callow sections the slime overflow of the drag classifiers is repumped to the secondary flotation cells. In the Inspiration sections, 0.425 sq. ft. of actual open porous surface and 0.615 sq. ft. of flotation machine area are provided for the treatment of one ton of ore in twenty-four hours.

FLOOR SPACE

The total floor space of the flotation floors amounts to 25,200 sq. ft., or 1.75 sq. ft. per ton of ore treated in twenty-four hours (rated capacity). The total floor space occupied by the concentrator proper (not including, however, the crushing plant located at the mine) is 81,900 sq. ft., or 5.68 sq. ft. per ton of ore, and the total floor space, if the settling-tank installation outside the main mill building is also included, is 258,890 sq. ft., or 17.4 sq. ft. per ton of ore (rated capacity).

WATER CONSUMPTION

The water added to the pulp where it reaches the flotation machines is about three tons of water for each ton of solid pulp. The subsequent treatment, in our case, requires a further addition of nearly three tons of water per ton of dry ore. However, as it is carried out on pulp that has been deprived of its slime contents by passing it over drag classifiers, the water thus entering the table tailings can be easily removed again. This is accomplished in our case by settling the table tailings separately from the slime tailings. The settling of the sand tailings is effected in a settling tank of home construction, consisting of a rectangular box with a sloping bottom into which a number of Caldecott cones are inserted. The resulting overflow is not quite clear, but is made so by resettling in three 60-ft. Dorr tanks.

Out of the total quantity of water actually added to the ore during its passage through the mill, amounting approximately to six tons of water per ton of ore treated, as mentioned above, nearly three tons, *i.e.*, the amount added during the table treatment can, as explained above, be reclaimed rather easily. For the reclamation of the rest of the water, settling ponds, of the well-known construction in which the reservoir is formed by building a retaining wall of sand across a gulch, are resorted to in addition to Dorr thickening tanks.

RECOVERY

The recovery obtainable by the application of our milling process is determined entirely by the composition of the ore, *i.e.*, by the relation between sulphide and oxide copper contained in the ore. Our average sulphide copper extraction has been 90.39 per cent for the months of March, April and May, 1916, the last months for which figures were available at the writing of this paper. A certain recovery of the oxide-copper minerals, especially carbonates, is made in the flotation process as well as in the gravity concentration process. The percentage of such mineral recovery is low, probably around 25 per cent. For this reason the recovery obtainable on ore containing a high amount of oxide, such as surface ore, is correspondingly lower. We have worked in the laboratory with the object in view of increasing the oxide recovery; for instance, by adding certain chemicals to the flotation pulp. An account of the results obtained will be found below, but we have not yet applied this method to an operating scale, nor have we decided on using one of the other methods applicable for this purpose, such as leaching.

Table 5 gives an average screen analysis of the feed and the general tailings of the Inspiration concentrator for the months of March, April and May. A segregation is made in the copper assay between sulphide and oxide copper, because, considering the present stage of the art, we feel satisfied with our mill work whenever the sulphide copper content of the mill tailings is low. As will be seen from the tabulations, a better recovery is made on the —200 material than on the coarser constituents of the ore, which proves the point that for ores of the character of Inspiration ore, sliming is not to be feared since the introduction of the flotation process.

OIL CONSUMPTION

Experience has shown that in the flotation treatment of our ores we consume flotation agents up to $1\frac{1}{2}$ lb. per ton of ore. At present, the oil mixture contains around 95 per cent crude coal tar and a little less than 5 per cent of oils derived from the dry distillation of wood.

The different tars that we have tested during the operation of our mill have shown greatly varying qualities as far as their flotation value is concerned. The first tar that we tested and made use of was homemade from domestic coal, and happened to be a very serviceable flotation agent. Since that time we have tested tars from several States, and have found some that are suitable for our purposes, while others are less so, and still others even entirely unsatisfactory. We have obtained satisfactory tar products from New Mexico, Colorado, Missouri and Illinois. These States furnish at present as much as we need for our consumption. For awhile it seemed possible that we might have to import from a long distance the large quantities of tar that we require. During that period we tried to find substitutes, and looked especially toward the utilization of fuel oil for this purpose, but we have not been able to get as good results with any kind of fuel oil as with crude coal tar.

TABLE V—AVERAGE SCREEN ANALYSES FOR THE MONTHS OF MARCH, APRIL AND MAY, 1916 OF FLOTATION FEED AND GENERAL TAILS

Mesh	Flotation Feed				General Tails							
	Per Cent Weight		Copper Contents		Per Cent Weight		Sulphide Copper Contents		Oxide Copper Contents		Total Copper Contents	
	Cum.	Indiv.	Per Cent	Grams	Cum.	Indiv.	Per Cent	Grams	Per Cent	Grams	Per Cent	Grams
+ 65	9.5	9.5	0.45	0.042	9.5	9.5	0.18	0.017	0.12	0.011	0.30	0.028
+100	21.2	11.7	0.86	0.101	21.2	11.7	0.19	0.023	0.14	0.016	0.33	0.039
+150	33.5	12.3	1.91	0.235	33.5	12.3	0.11	0.014	0.19	0.023	0.30	0.037
+200	39.2	5.7	2.69	0.154	39.2	5.7	0.14	0.008	0.19	0.011	0.34	0.190
−200	...	60.8	1.85	1.125	...	60.8	0.06	0.036	0.47	0.286	0.53	0.322
Totals	...	100.0	...	1.657	...	100.0	...	0.098	...	0.347	...	0.445
Assay direct	...	....	1.62	....	...	....	0.101	....	0.318	....	0.419	
xide	...	....	0.36									

Our experience is that we can get along with coal tar alone. It is beneficial, however, to add wood-distillation products in small quantities, for instance, those containing pine oil. While coal tar makes a very strong and heavy froth, such as appears to be required to keep coarse mineral particles in suspension, the wood-distillation products have the characteristic of producing a

multitude of froth bubbles, such as seem necessary to furnish the large surface required to save the very fine mineral particles. Because the finer ore particles, as (slime) on account of their small diameter, expose a large surface, it is evidently necessary to produce a correspondingly large surface of froth in order to save them by flotation.

OPERATING COST FOR FLOTATION

The number of men necessary for the operation of large flotation machines is remarkably small. At the Inspiration plant one operator supervises four sections of flotation machines. Two Mexican helpers assist him in washing the bottoms, thus insuring a free passage of air through the porous medium. At the prevailing high prices of American and Mexican labor, this means an expense of somewhat more than 1.5 cents per ton of ore treated. The total expenses representing flotation proper were as follows for the months of March, April and May, 1916:

	Cents per Ton
Labor	1.62
Flotation oils	1.65
Other supplies	0.35
Power	2.14
Total	5.76

The subsequent table treatment of flotation tailings, the filter treatment of the concentrates and other operations connected with the process of concentration, belong more or less to flotation treatment, and their expense should also be considered when the cost of the flotation process is to be established. The total milling cost, exclusive of crushing and grinding, has been for the past few months in the neighborhood of 20 cents. When the cost of crushing and grinding is included, the cost is about 40 cents per ton of ore. Royalties for the use of the flotation process are not included in any of these cost figures.

DISCUSSION OF RESULTS OBTAINED

The criticism has occasionally been raised against the Inspiration company that they were slow in deciding on the design of a concentrator. The reason for such slowness was, of course, that the development of the flotation process coincided with the period during which the fundamental points in the design of the concentrator had to be settled. The management, therefore, thought it best to be very conservative in installing standard concentrator equipment, which, in case the new process held what it seemed to promise, might prove to be entirely superfluous. The main point of interest, therefore, is whether it was wise for the company to wait instead of installing a gravity concentrating plant as had been originally considered.

As far as the comparison of a flotation plant, as at present operated by the company, with the gravity-concentration plant, as originally considered, is concerned, the recoveries actually obtained in the company's flotation plant are so much higher than those indicated by tests in the original test mill as being obtainable in a gravity-concentration plant on ore of the same character, that there cannot be the least doubt which system is the better.

In discussing the second question which comes up in this connection, whether for ores of the character of Inspiration ore, gravity concentration supplemented by flotation would be preferable to the simple flotation process that has been adopted by the Inspiration company, the crucial point is this: Can the slime be reduced to lower copper contents by a combined process than by the process followed here? The reduction of the copper in the sand is, as millmen know, simply a question of fine grinding combined with suitable concentration.

In support of the principle followed by the Inspiration company, I desire to call attention to the screen analyses of our general tailings represented in Table 5. They show that the sulphide copper left in the —200-mesh material is very low.

In addition, the floor space required for a plant like this is materially smaller than for a plant of the combination plan, which also means that the construction cost is much lower; and further the operating costs are low by reason of the greater simplicity of design. I hope these facts are sufficient to decide the point at issue as far as the ore of this district is concerned.

I hope that our neighbors of the Miami company, whose mill was built before the flotation process was known, will uphold me in my statements. If this point is admitted, it will endorse the principle followed in the design of the Inspiration mill, of doing away with reduction in stages and concentration in stages.

It must be granted that the settling of flotation-concentrate pulp requires extensive floor space, as shown by the figures referred to above, and that settling and subsequent filtering absorb a certain fraction of the mill operating costs. However, as a ratio of concentration in the Inspiration mill is 25 into 1, only 1/25 of the ore is thus treated. The actual expenses increase, of course, proportionately for ore which does not permit concentration with such a high ratio as the ore existing in the Inspiration mine. Therefore, there will be a point beyond which a different system of concentration is preferable. Just what the critical ratio of concentration is must be determined by calculation and testing based on individual conditions.

Prospects for Future Development of the Flotation Process

The flotation process is in its infancy. For this reason, therefore, our concentrator must be necessarily in the first stages of its development. In what direction future changes may take place is perhaps indicated by tests which have been made partly on a laboratory scale and partly on a somewhat larger scale, but which have not yet been incorporated into our regular milling process. Of these latent developments I will try to give an outline in the following:

POROUS-BOTTOM EXPERIMENTS

The porous bottom is, as one may imagine, the most essential part of a pneumatic-flotation machine. Our experience with the porous bottoms of the different constructions brought out very clearly the principal difficulty attached to them, which is, that the pores have a tendency to contract gradually and thereby to retard the passage of air through them. This tendency was more pronounced in the solid porous bottoms employed in the Flinn-Towne flotation machine than it was, for instance, in those of the Callow type, although the latter also show a tendency in this direction.

Our first supposition was that the choking was due to the fact that the air entering below the blankets carried particles of dust, which would settle in the fine pores and reduce their area. Indeed, a canvas blanket will, after a certain length of service as a porous medium, always show some ring-shaped spots of dark color opposite the air inlets, clearly indicating that a deposition of dust particles on the blanket actually does take place.

To make sure of this point we cut out round disks from a Callow blanket that had been used for some time and investigated their porosity by using them as porous bottoms in a glass tube standing in a vertical position. Air under pressure could be applied to an air chamber

located underneath these disks, and the air passing through the porous blanket could be measured by a gas meter. The quantity of air discharged through the porous medium offers a measure of the porosity of the blanket, and for this reason the velocity or speed with which the counter of the gas meter revolves, gives an indication of the porosity of the porous disks being tested.

To our surprise, we found that the darkest points of the blanket were not those of lowest porosity. On the contrary, the points farthest away from the air inlet showed the greatest tendency to choke. An explanation of this paradoxical behavior seems to be offered by the fact that an air blanket is kept in a state of more or less agitation near the air inlet (in the Callow machine this happens to be a point remote from the places where it is held rigid) while farthest away from this point the blanket assumes a state of comparative rest. Incrustations, due perhaps to the presence of soluble salts in the water in conjunction with fine slime, always form to a greater or less extent in the top layer of the blanket. Evidently, the agitation counteracts the formation of the incrustation, while there is no such counteracting influence in the portions which are essentially at rest.

For this reason we concluded that a solid porous material is not suitable as a diaphragm in a flotation machine of the pneumatic type, if a bottom of long life is required. As a matter of fact, the experience of everybody who experimented with solid bottoms seems to have pointed in the same direction. Mr. Cole for a while tested out carborundum tubes in his machine. We tried carborundum stones in the flotation machine of the inspiration type and abandoned them, and I believe that even Messrs. Flinn and Towne have, in the meantime, give up the solid bottom of their origial design.

A necessary condition for a serviceable flotation bottom appears, therefore, that the porous medium be of a flexible nature. The four-ply canvas stitched every half inch or so which Mr. Callow's first cells contained and which we have used for considerable time in the Inspiration machines, seems to answer this purpose fairly well. We find, however, that to keep it in good working condition and prevent incrustations from forming on the top, we have to clean it frequently. This is done by dipping an iron pipe connected with the water hose into the compartments and sweeping the canvas bottom with the jet of water discharging from the lower end of the pipe.

The canvas blankets seem to last for about six months at the most. As they are inexpensive, the replacing of a bottom after that time is not a serious item in the operating costs. The giving out of the canvas is due to the wear caused by the frequent cleaning. The top layer wears out first, the holes created by the stitching forming nuclei for the formation of larger holes. By the time the top layer has a number of holes the canvas blanket is generally discarded. In the interest of greater economy we intend giving up interstitching the layers of canvas. We are trying to decide whether it is better to use single sheets of thicker fabric or to use canvas similar to the kind that we have been using and to put several layers on top of one another without interstitching them. The latter has the advantage of requiring the discarding of only one layer, when it becomes defective.

There will always be some tendency to form incrustations so long as canvas is used for flotation mediums. Their formation will be entirely prevented only by substituting an altogether different material. We have made experiments in this direction. One of my former assistants, R. H. Haskell, deserves credit for suggesting them. For instance, we substituted for the canvas blankets thin rubber sheets perforated with a multitude of needle holes and obtained an excellent froth. The objection to their use is that their life is limited. When sheets of rubber of an increased thickness are used, the needle holes require too much pressure to form openings of sufficient size for the passage of air, and to make a thick rubber sheet suitable for this purpose, slits several millimeters long have to be substituted for needle holes. We have had one or two rubber bottoms of this design in operation, but just at present we are not ready to substitute them for canvas blankets. We also tried a blanket made from a material that goes under the name of sponge rubber and can be produced with rather fine texture. We have not been able, however, to obtain lastingly good results from the use of this medium. Furthermore, we tried a woven fabric containing rubber threads in one direction and threads of cotton or the like in the other direction and a rubberized canvas made by the Goodrich Rubber Company. We are not prepared to use any of these materials on a commercial scale.

The advantage of rubber should be, in the first place, that on account of its smoothness it would have less tendency than canvas to permit the formation of incrustations. Besides, an elastic medium should have the additional advantage of avoiding the danger of catching small sand or slime particles in the pores of the medium, as an expansion of the medium (that may be effected, for instance, by increasing the pressure) would widen the pores and remove such particles. We think that our experimental work in this direction is encouraging.

RAISING THE GRADE OF CONCENTRATES

The recovery that it is possible to effect in a flotation plant depends largely on the grade of concentrate desired. With a low grade of concentrate, low tailings can be made, but when a high grade of concentrate is stipulated, increased tailing losses cannot be avoided. A question that suggests itself in this connection, and which we have tried to answer by laboratory experiments, is, "How can we raise the grade of our concentrates—that is, reduce the percentage of insoluble matter contained in them—without entailing additional copper losses?" We know from laboratory experiments that this can be done by expensive methods—for instance, by heating the solutions—but such a procedure would be undesirable from an economical standpoint. Experience has shown us that concentrate produced in the first compartments of the cleaner cells is always freer from soluble matter than the concentrate produced in the last compartments. The problem then resolves itself into finding a suitable cleaning process for the concentrate from the last compartments of the cleaning cells. By treating this low-grade concentrate hot, with the addition of caustic soda, we have been able to separate it into a high-grade concentrate and fairly low tailings. This method necessitates only the expense of heating a small fraction of the pulp and may be a commercial possibility.

RECOVERING CARBONATES BY FLOTATION

Another subject on which we have spent considerable time in our laboratory is the problem of recovering copper carbonates by flotation. When we started our flotation plant we discovered, to our astonishment, that the machines not only saved a high percentage of copper sulphide, but that they also recovered some of the carbonates. Ever since that time we have tried to find means of improving the carbonate recovery.

In the first place, we studied all of the oils that seemed to have a tendency to cause the flotation of such minerals. Later on we tried other means in addition

to the variations of the oils. One way in which copper carbonates and similar minerals might be recovered was outlined by Alfred Schwartz in his United States Patent No. 807501. The process consists in first artificially producing a sulphide coating on such oxidized minerals by the introduction into the pulp of soluble sulphides, and then adding suitable "oils" and effecting the flotation. If it were possible to thus chemically produce coatings of sulphide identical with the surface of the minerals formed by nature, this process would work well, as evidently the nature of the surface is the only characteristic that determines whether a mineral will float or not.

The Minerals Separation Company owns a number of patents covering this subject. Their English Patent No. 26019, issued to Sulman and Picard, describes the flotation of oxide copper minerals by similar means.

I am not aware that equivalent patents have been issued in the United States. The English patent in question is of a later date than the Schwartz patent above mentioned. The representatives of the Minerals Separation Company have experimented more or less extensively with this system, while demonstrating their machine to the Inspiration company. As far as I know, they have not proved its practicability.

In the course of their experiments they tried the application of sodium sulphide and sodium polysulphide for this purpose. The latter was produced by treating sulphur with hot caustic soda. At the time these experiments were made, I was not familiar with the chemical action taking place, which, as much as I know now, actually results in the formation of polysulphide mixed with thiosulphates and other oxygen-sulphur compounds. The failure of their experiments I therefore ascribed to the fact that perhaps a polysulphide which they were anxious to make was not actually produced.

I proceeded to make sodium polysulphide by a method which I knew, that is, by the treatment of a sodium sulphide solution with sulphur powder. When we applied this reagent to some of our carbonate ores in laboratory flotation experiments, we noted that a good recovery was obtained. The composition of the compound was varied materially in order to find just what composition gives the best results in the flotation of carbonates. Our experience seems to indicate that sodium sulphide alone encourages the flotation of carbonates, but that sodium polysulphide or sodium sulphide, which contains more sulphur than would correspond to the chemical formula Na_2S, gives better results. The addition of caustic soda besides the sodium polysulphide was found beneficial.

The question then arose as to why we succeeded in effecting the flotation of oxidized copper when the experiments of the members of the Minerals Separation staff failed. Tests along these lines brought out the fact that the Minerals Separation compound when applied to our carbonate ores also worked successfully, but that it did not on our regular milling ore. Our own compound when added to our mill ore mixture increased the recovery of the carbonates, but evidently interfered with the sulphide extraction, and for this reason seemed to be of as little use as the compound of the Minerals Separation Company. When applying reagents of this character to tailings resulting from ordinary flotation treatment, with the point of view of effecting a sufficient sulphide extraction by the regular flotation process, and using the compound in question only for the purpose of increasing the carbonate extraction, we have found so far that the increase in copper-carbonate recovery over the one obtained without the addition of such chemical compounds is not worth going after.

But this is only a consequence of the fact that carbonates exist in very small amounts only in our milling ore and are partly saved by the ordinary flotation process.

There is no real difficulty about saving carbonates by the method mentioned, if they exist in quantities that make it worth while to save them. That copper carbonates can be recovered may easily be demonstrated by treating a deslimed feed in a series flotation machine. If at the point of the machine where the sulphide recovery is nearly finished sodium sulphide is added, the decidedly green color of the concentrates in the following compartments leaves no doubt on this point. The desliming of the feed seems to assist in the carbonate recovery.

It is of considerable (even if only theoretical) value to establish why sodium sulphide and polysulphide tend to increase the recovery of copper carbonates. A coating that might be expected to form cannot be detected. The concentrate resulting from the treatment of pure carbonate ore is decidedly green; besides, when an alkaline condition of the pulp is used there is very little, if any, tendency for any sulphide coating to form, and the alkaline state of the pulp is (as explained above) exactly the condition under which the best carbonate extraction results. Another point that seems to contradict the explanation of these results by the assumption of a sulphide coating is, that when we proceeded exactly as suggested by Mr. Schwartz, *i. e.*, when the application of soluble sulphide was followed by the addition of flotation agents and by the actual flotation—we seemed to obtain poorer results than when the procedure was reversed by applying the oil first and following with the application of some soluble sulphide, although the latter method would certainly seem less favorable to the formation of a sulphide coating, and perhaps for this reason has not been suggested by Mr. Schwartz.

Another theory that has been mentioned as an explanation of this phenomenon is that colloidal sulphur is formed by the solution of sodium polysulphide in water, which, as is known, is a good flotation agent. For instance, it is pointed out in the United States Patent No. 1140865 taken out by Dr. R. F. Bacon of the Mellon Institute in Pittsburgh, that by setting free colloidal sulphur, say by the reaction of a soluble sulphide with sulphur dioxide, good flotation results may be obtained as far as the flotation of sulphides is concerned. To make the process available for the flotation of carbonates and other oxidized copper minerals, he suggests that a sulphide coating be first formed on the minerals, *i. e.*, to follow Mr. Schwartz's idea. Whether the colloidal sulphur by itself has a beneficial influence on the recovery of the carbonate (as has been suggested in explanation of our observations) seems rather doubtful when it is considered that we have obtained good results in alkaline solutions in which colloidal sulphur does not seem to separate out from polysulphide containing only a limited amount of sulphur such as was used in our tests. The full theoretical explanation of these facts must therefore be left to future investigations.

RECOVERY OF SILICATES

In our experiments with the object of saving the oxidized copper minerals, we soon found that we could save some of these minerals, while others were entirely refractory to the method above mentioned. To establish which minerals could be saved and which not, we attempted an analytical separation into carbonates and silicates. The chemical methods which we tried for the purpose of distinguishing between the two proved unreliable, however, and we had to resort to the separation by specific gravity (panning). The carbonates of copper (malachite and azurite) are heavier than gangue, and the silicates (chrysocolla) are lighter. The separation is rather difficult, owing to the small difference in

specific gravity, and the results are therefore far from being altogether reliable, but they seem accurate enough to indicate that the method of saving carbonate copper above referred to is of value only for the recovery of carbonates and does not apply to silicates.

This fact seems to be another corroboration of the assumption made above, that carbonates of copper do not float simply because of the formation of a thin surface coating of copper sulphide. It can easily be verified in the laboratory that silicates can be coated with copper sulphide fully as easily as copper carbonates. For this reason, if the filming theory is right, it should be possible to float silicates just as well as carbonates. There is no doubt that they can be floated by transformation into sulphides, only this transformation must not be confined to the surface, but must go deeper. Our experience is that to effect a good recovery it is necessary to acidify the pulp so strongly that practically all of the silicates of copper are dissolved and by the action of hydrogen sulphide or other soluble sulphides are transformed into the state of chemically precipitated copper sulphide. In this form there is no difficulty about the recovery of the copper by flotation, but this procedure is not entirely without objection.

In case hydrogen sulphide gas is used, the acid combined with copper is regenerated. This tends toward a low acid consumption and a good copper extraction, on account of the fact that the treatment winds up with a small percentage of copper in solution and free acid present, both of which are desirable in the light of the law of chemical mass action. But hydrogen sulphide is not a desirable reagent. The fact that it is a gas and not a liquid introduces complications in the apparatus which are accentuated by the fact that it is poisonous and obnoxious otherwise.

Other soluble sulphides used in place of hydrogen sulphide will neutralize some sulphuric acid with the result that the acid consumption will be higher and the copper extraction lower than in case of hydrogen sulphide gas.

As far as acid consumption is concerned, it is pointed out that the free acid lost with the pulp may be settled out in ponds and re-used. However, the re-use of acid diluted to such an extent is a more serious problem than is generally realized.

The treatment of concentrates that are "colloidal," to a much greater extent than ores which millmen have been in the habit of calling colloidal, offers additional problems, which, however, may prove not to be as serious as they look.

Everything considered, I cannot see that the flotation treatment of oxidized copper ores after previously leaching them offers better prospects than straight leaching by decantation and precipitation by other methods.

General Theory

Very much has been published recently about the theory of the flotation process, and very many suggestions have been made that will probably prove valuable after it has been shown by critical tests how far they explain the facts.

It seems to me that an explanation of the qualities of the flotation oils is not as difficult as it might appear. The problem only seems so complicated because the flotation qualities of an oil or an oil mixture have not been separated into their components. In fact, it requires a combination of qualities to make a successful flotation oil. In the first place, the flotation oil has to coat the mineral particles. That there is a tendency for the formation of such a coating can easily be seen from simple experiments. For instance, if samples of copper sulphide (chalcocite), copper carbonate (malachite) and gangue (silica) of the same screen size are spread out on watch glasses and then moistened with a drop of coal-tar creosote, it will be seen that the drop of creosote soon disappears through absorption by the copper sulphide, while it takes a much longer time for it to be absorbed by the copper carbonate and a still longer time with the gangue. On the other hand, when a drop of water is placed on the same minerals, it will disappear on the gangue first, later on the carbonate, and finally on the copper sulphide. This evidently proves that in a mixture of water and oil, the oil will attach itself with preference to the sulphide particles while the water will have the greater tendency to wet the gangue.

The second quality which at least is sometimes required of a flotation oil is that it has to form a stable froth. In such a case the stability may be secured by more firmly cementing together the mineral, air and oil. To accomplish this, oils are used which have a tendency to float finely divided gangue particles. The action is characteristic of the heavier pine distillates like pine tar and the lighter ones like turpentine if they are crude, unrefined products; in other words, when they contain some of the heavier distillates. I am not quite sure, however, whether the beneficial influence of oils of this group is not perhaps rather due to the fact that they remove colloidal material from the pulp and thereby improve its tendency to float minerals.

A third quality demanded of a successful oil mixture is that it must be able to produce a sufficient volume of froth. This property is exemplified best by oils of the soluble type—cresol, pine oil, alcohols and other substances. It can easily be proven that when oils of this type are used, although they may be considered insoluble, the water acquires the frothing qualities of the oil. It may be demonstrated by shaking an oil of this character, with water and permitting the oil to separate out again. It will be found that the water has acquired frothing qualities by undergoing this treatment. It is perhaps even likely that the soluble portion of the oils belong to this group is the only portion that is active in this manner. The difference between the oils of group 1 and group 3 may be studied, for instance in a flotation machine of our type. It will be noted that the heavier mineral runs over the concentrate discharge largely in the first compartments forming a heavy, dark froth and the heavy insoluble portions of the flotation oil mixtures apparently go with it. Toward the tailings end of the flotation machines, most of this dark material has disappeared and the froth is lighter and of a more watery nature. The pulp, however, has not lost the quality of forming froth even after it gets to the last compartment of the flotation machines. This permits the conclusion that the frothing characteristics follow the tailings pulp. The water settled out in tanks and tailing ponds has decided frothing qualities. Such water behaves in a similar way to certain alcoholic solutions with which we are used to associate this characteristic, for instance, beer or champagne. The experience of mills using the flotation process, that when the tailings water is reclaimed the quantity of frothing oil may be considerably reduced, further supports the assumption that the formation of froth is caused by water-soluble substances.

Just how the surface tension of water and air must be modified to permit the formation of froth has been made the subject of some speculations recently published by different authors. We have also devoted some thought and a few experiments in our laboratory to this question. A discussion of these matters belongs to the realm of physics, however, and is outside the scope of this paper. But I might add this remark to the discussion of the subject of flotation oils, that most flota-

tion oils not only have the characteristics of one group, but may at the same time possess those of another one. For instance, coal tar has qualities 1 and 3. For the flotation of our ordinary milling ore we do not require much of the quality of oil classified in group No. 2, and, therefore, can get along with coal tar alone. But we find it advisable to add to the coal tar more of the qualities characteristic of the third group, and for this purpose we add about 5 per cent of the total in the form of crude pine oil. In many cases it is found that the flotation oil has the characteristics of group No. 2 to such an extent that it is impossible to make clean concentrates. Various chemical means, such as the addition of acid or alkali, are used to counteract this.

CONCLUSION

In summing up I want to say that the fact that the Inspiration company has been able to design a commercially successful flotation plant and has found ways that hold out prospects of raising the plant to a very high state of efficiency, must be attributed to the policy followed by the company of spending great sums of money for the purpose of investigating the flotation process on a commercial scale. In carrying out these investigations, a close coöperation between laboratory and operating force helped us, I believe, more than anything else. I would like to give credit to each person who had a share in contributing toward the success of the work, but cannot do it, because the list would be too long.

Inspiration Consolidated Copper Company, Miami, Ariz.

Chemical Composition Versus Electrical Conductivity*

By Colin G. Fink

Some years ago, while still at the University, I carried out a number of experiments on the electrothermic production of ultra-marine. Powdered mixtures of sodium sulphide, china clay and carbon were interposed between carbon electrodes in a closed crucible furnace. I observed at that time that in order to keep the electrical resistance and the temperature of the charge fairly low so as to avoid decomposition of the ultra-marine as soon as it was formed, it was necessary to use very finely divided carbon, such as lamp black. With charges made up of powdered coke which was coarse compared to the lamp black, I could not get any appreciable current to pass between the carbon electrodes up to potentials of 250 volts. Subsequently, I have found repeatedly that the electrical conductivity of mixtures of finely divided substances is a function of the relative size of the components.

Experimental

A series of tests was made in order to get values of a more quantitative nature. Two substances were selected, the physical properties of the one as divergent as possible from those of the other: A black metal powder, tungsten, and a white insulator powder, thoria. The advantages in this selection are manifold: Both tungsten and thoria will stand very high temperatures and can therefore be made practically moisture-proof. It is a well-known fact that in all high resistance tests adsorbed moisture is a very disturbing factor. As regards metals such as copper and silver, these were not serviceable since they cannot be heated to high temperatures without partial vaporization, which though slight was sufficient to cover the surface of the insulator granules with a highly conductive film. Other factors that decided our selection in favor of tungsten and thoria were: (1) high state of purity; (2) availability of both in extremely fine powdered form (readily sifted through 250 mesh silk gauze); (3) constancy and stability under ordinary atmospheric conditions; (4) sharp distinction in color; (5) high specific gravities (which reduced the tendency to dust).

All mixtures here recorded were made up of equal weights of tungsten and thoria. As regards the size of the particles, as stated above, the mixtures would pass readily through silk having 250 meshes to the inch. The holes in this silk are about 0.001 in. in diameter.

Attempts to segregate particles of a well-defined size by such methods as suspending in water, or in organic liquids or in air, were frustrated on account of the persistent tendency of the very fine particles to form agglomerates.

We finally resorted to the familiar "tap test." This gave us fairly good comparative values of the fineness of the various powders used. Ten grams of the powder or powder mixture were filled into a 10 c.c. glass graduate and tapped to constant volume; usually after seven minutes, no further decrease in volume could be detected. The ultimate volume in cubic centimeters divided by 10 gave us the relative volume (v_r) as recorded in Table I. It can easily be demonstrated, that the values for v_r are a function of the density and mean particle size. At first there seemed to be a serious objection to the tap test, namely this, that a powder composed of say, equal parts of coarse and fine particles would give the same value for v_r as a second powder whose particle size was a mean between the two limiting sizes of the first powder.

This objection to the tap test was automatically set aside since in the ordinary preparation of metal or oxide powders in single small lots by far the greater majority of particles are approximately of the same size. This tendency to form a "standard" size is a universal phenomenon, the dimensions of any particular standard being dependent upon the physical factors such as temperature, strength of solution, etc., under which the particular powder is prepared. Compare in this connection the uniform size of the crystals of granulated sugar as regulated by the "strike pan."

Table I

Mixture	Relative Volume (V_r) of ThO$_2$	W	Mixture Found	Mixture Calculated	Appearance of Mixture
R	.7 20	.1 13	.4 30	.4 17	White
P	.7 20	.3 50	.5 65	.5 35	White
Z	.5 76	.2 35	.3 89	.4 06	White
T	.3 05	.1 13	.2 00	.2 09	White
S	.3 05	.3 30	.2 75	.3 18	Black
X	.2 38	.5 77	.4 20	.4 08	Black

Referring to Table I, we note that the white thoria powders varied in relative fineness between 0.720 and 0.238 and the black tungsten powders between 0.577 and 0.113. In column 5 the calculated value for v_r of any mixture is equal to one-half the sum of the v_r values of the ThO_2 and W constituents. These calculated values agree fairly well with the experimental and support our contention that the particles of any freshly prepared powder are of fairly uniform size. If this were not the case no such agreement between the values of columns 4 and 5 were possible. In the last column of the table is given the appearance of the mixture, whether nearly white or nearly black. If the v_r value for the white powder is high as compared with the v_r value for the black powder, the appearance of the mixture is white; if the white powder is coarser than the black powder, the appearance of the mixture is black. In other words, whenever the ratio of v_r for thoria to v_r for tungsten

*A paper presented at the New York City meeting of the American Chemical Society in the Symposium on Colloids, on Sept. 28, 1916.

is greater than 2, the mixture is white and if less than 2 the mixture is black, where 2 is equal to the absolute density of tungsten (19.6) divided by the absolute density of thoria (9.8).

Electrical Measurements

The powders were pressed into rods 4 cm. long and ½ cm. square. They were then placed into a tungsten hydrogen furnace and fired at 1600 deg. to 1650 deg. for three hours. This firing caused the rods to sinter together and rendered them practically proof against moisture. The fired rods were kept in a P_2O_5 dessicator. The rods were then mounted between brass clamps and the resistance measured on a Wheatstone bridge with a sensitive galvanometer. Care was taken to make these measurements on days when the humidity of the air was low. (Compare in this connection H. L. Curtis, Phys. Rev., 3, 490 "Surface Leakage over Insulators.")

In view of the differences in "color" of the various mixtures in the powdered form, it was not very surprising to find marked differences in the electrical resistances. The firing at 1600 deg., however, resulted in an almost uniform shade for all of the mixtures. In the table (II) below are recorded four of the characteristic resistance values found.

In the last column are the calculated specific resistance values.

TABLE II

Powder	Resistance Over 10^{12} Ohms	Resistivity Over 10^{12} Ohms
ThO_2 No. 2		
Z	41.8	173.0
X	0.0271	0.108
W No. 1	0.0040	0.016

The powders, ThO′ No. 2 and *W* No. 1, were pressed up into rods of the same size as those of the mixtures; they were likewise fired at 1600 deg. for a period of three hours.

Since in all of our original powders a small percentage of grains was present whose size was considerably smaller than that of the majority of the grains, our results would tend to show that under ideal conditions of mixture, relative grain size, uniform distribution, etc., the resistivity values for white mixtures such as *Z* would be even higher than here recorded. Similarly, the resistivity values for black mixtures such as *X* would be even lower than those found, approaching a limiting value equal to twice that of the 100 per cent metal rod.

Conclusion

In general we may say that the electrical conductivity of a substance is primarily dependent upon the shape and the distribution of the fundamental grains or particles composing the substance, and secondly, upon the presence or absence of thin films of secondary material enveloping these ultimate grains.

On the basis of this theory we can account for the comparatively high conductivity of gels that contain but a trace of conducting material. We can also account for the marked difference in resistance for example of two samples of commercial copper, whose chemical composition is identical, depending upon whether the impurity, such as sulphur, is uniformly dissolved in the metal or whether it forms a film ("cement") of copper sulphide around pure granules of copper. The latter case is to be regarded, as Bancroft suggested, as an emulsification of copper in copper sulphide. The high resistance of these surface films composed of say sulphide or oxide or arsenide accounts for the high resistivity values of copper when but a trace of the impurity is present.

Electrolytic Zinc Dust*

By Harry J. Morgan and Oliver C. Ralston

The sudden increase in the price of zinc dust after the beginning of the European war, owing to the cutting off of the German and Belgian supply, led to the conducting of some experiments on the possibility of its production on a commercial scale from solutions of zinc, and the substitution of the zinc made in this manner for the zinc dust ordinarily used in the precipitation of gold and silver in the cyanide process.

As the Salt Lake City station of the U. S. Bureau of Mines, in co-operation with the Department of Metallurgical Research of the University of Utah, is carrying on investigations that have for their object the treatment of low-grade and complex zinc and lead ores or products, it was thought well to determine whether the zinc contained in such ores and products could not be utilized in the manner above indicated, and so supply the demand which had arisen for zinc dust.

The United States, in 1913, imported 4,382,470 lb. of zinc dust, valued at $227,585. Most of this was from either Germany or Belgium. The domestic production, in comparison with the imports, was very small. In the years 1912 and 1913 the domestic production was 492 and 423 tons respectively, while the imports were 2,400 and 2,200 tons respectively. For a time the zinc dust made in zinc smelters was a drug on the market and when first utilized in cyanidation could be bought for a lower price per pound than solid zinc. After the advantages of the use of zinc dust for precipitation were realized, so much zinc dust began to be used for this purpose that it brought a premium of about 3 cents per pound over what the value of spelter was at the beginning of the war. Since that time its price has averaged about 30 cents per lb., without much fluctuation. South American zinc smelters have undertaken to supply the demand but their product has never been equal to the German zinc dust.

Some attempts by Morgan[1] were made in the application of a jet of air to atomize a column of molten zinc for making zinc dust. This work was carried on at the Bureau of Mines Exhibit at the San Francisco Exposition, but the zinc dust was not satisfactory for cyanide precipitation. While it was fine enough to pass a 200-mesh screen, it was only 25 per cent efficient in the precipitation of silver from cyanide solutions and a microscopic examination showed that the small pellets of zinc were in the shape of congealed droplets which present a minimum of surface for reaction with the silver cyanide solution. This idea has been further carried out at Anaconda and we are informed that 10 to 15 tons of atomized zinc is now being prepared per day, in preference to sponge zinc made by electrolytic deposition from sulphate solutions. This dust is being used for purification of zinc sulphate solutions, for the reason that the more finely divided electrolytic sponge tended to clog up the Shriver filter presses used at that plant.

To us, a better idea seems to be the making of a zinc sponge by electrolytic methods, the sponge to be of such a nature that it would crumble to dust when dried. The variety of electrolytic conditions available,

*A paper read at the New York meeting, American Electrochemical Society, September 28, 1916, by permission of the Director, U. S. Bureau of Mines. Communicated by D. A. LYON, Metallurgist in Charge of Salt Lake Station of Bureau of Mines. Mr. H. J. Morgan is Research Fellow, University of Utah; O. C. Ralston is Assistant Metallurgist, U. S. Bureau of Mines, at the Salt Lake Station.

[1] In this work Morgan was assisted by Dr. R. H. Bradford, Professor of Metallurgy, of the University of Utah, and the work was carried out under the direction of C. H. Clevenger, Professor of Metallurgy at Stanford University.

with the different electrolytes which can be used, and the resulting great differences in the physical properties of the precipitated metal, gave promise of the possibility of a zinc dust which would be highly efficient and rapid. As a result of the experimental work, which has been carried on, it is believed that this possibility has been realized. In addition to its use for precipitating gold and silver from cyanide solutions, zinc dust can also be used in sherardizing, and for chemical purposes, such as reduction of organic compounds, etc. Sherardizing requires a considerable proportion of relatively coarse particles of zinc, similar to the atomized zinc above mentioned, but it is possible that the manufacture of dyes and other such chemicals in the United States can create a considerable demand for electrolytically prepared zinc dust of high purity and efficiency. The following work was carried on with a view to preparing dust satisfactory for cyanide practice and does not consider the needs of the sherardizing industry, or of the chemical industries.

According to Sharwood,[2] zinc dust for use in cyanide precipitation should be fine enough so that 90 per cent of it will pass 200 mesh and it must be high in metallic zinc. A considerable amount of zinc oxide may be present without seriously affecting the efficiency of precipitation by the metallic zinc. The following method of testing the efficiency of precipitation by zinc dust is given by Sharwood. After passing the dust through a 100-mesh screen to break up the lumps, 303 milligrams are weighed out and added to 250 cc. of 1 per cent silver cyanide solution which contains 0.15 per cent free cyanide. The solution is stirred occasionally for two hours, after which it is withdrawn from the precipitated silver by filtration. The precipitated silver is dissolved in nitric acid and titrated with ammonium sulpho-cyanate, using a ferric salt as an indicator; or else the precipitated silver is scorified and cupelled to be weighed. Each milligram of silver precipitated represents 0.1 per cent efficiency of precipitation. This test is merely an empirical one of general acceptance which is admittedly near enough to allow of intelligent buying of zinc dust. It is stated by Herz[3] that the efficiency of zinc dust should be over 40 per cent and that dust with less than 30 per cent efficiency generally gives poor results. Dust of over 50 per cent efficiency is hard to obtain. The average grade of zinc dust from Europe is 45 per cent efficient, but in this work we have been able to get dust giving an efficiency of 74 per cent.

The usual endeavor of the zinc hydro-electro-metallurgist is to obtain solid reguline deposits of zinc rather than the sponge, as the sponge metal can rarely be melted down into spelter. The literature on electrolytic zinc is full of instances where work along certain lines was stopped on account of the "tendency" of the zinc to be deposited in a spongy form. However, we found that in duplicating this work and following the conditions as given, that there is only a *tendency* and that the average result of such conditions is trees, warts, or loose crystalline zinc. We found as much difficulty in obtaining a true sponge as the beginner usually finds in getting smooth solid deposits. Conditions of high current density and low current density, high acidity and low acidity, or basicity, high temperature, etc., were tested and it was very hard to get all the sponge that others had reported as being so easily obtained.

The writers have been informed that one metallurgical company produced several thousand pounds of zinc dust at their electrolytic zinc plant in Welland, Ontario, by allowing the temperature of their solutions to go up above 70 deg. C. and that it was used by one of the local firms with indifferent success. The electrolytic plant in question is operating a sulphate solution of zinc in which ore is suspended in the solution while the cathodes are protected by bags. Most of the sponge or the loose crystals prepared by us from sulphate solutions did not possess a very high precipitating efficiency. Spongy zinc was formed when solutions of zinc sulphate containing dissolved zinc oxide were used, but as soon as the solutions became acid, due to the formation of sulphuric acid at the anode, the zinc lost most of its spongy characteristics. An excess of zinc oxide suspended in an open cell is not desirable, as it mixes with much of the loose zinc sponge formed. Removal of the solution to an outside vat, for treatment with zinc oxide, is not desirable on account of the slow and low solubility of the zinc oxide in the zinc sulphate solutions.

The method of adding impurities to the solution was resorted to in order to get sponge zinc. Copper and arsenic were found to be most efficient for this purpose, but copper is not a desirable constituent in zinc dust on account of its presence in the precipitate of the precious metals. Arsenic is also undesirable in the precipitate, if the latter is to be treated with sulphuric acid before melting into bullion, due to the formation of poisonous arsine. All the copper was found to be deposited quite quickly from solution with the sponge zinc, but after the deposition of the copper, the zinc deposits began to be more solid and crystalline. A continual drip of copper sulphate into the electrolytic vat is hence necessary. The addition of iron as an impurity did not result in producing successful sponge zinc. Furthermore, the oxidation and reduction of iron salts at the electrodes lower the current efficiency.

The favorable results obtained in solutions made slightly basic encouraged the use of basic solutions of zinc, such as sodium zincate. The zincates allowed a wider latitude in the precipitation of zinc sponge than any other solutions tested. Lead anodes tend to dissolve, and zinc anodes dissolve almost quantitatively. Iron anodes are practically unaffected, especially those made of the better grades of iron. After doing this work it was discovered that practically the same idea had been patented by Sherard Cowper-Coles in British patent 13,977 of 1907. The electrical conditions best for this work are not mentioned by him, but we find that a wide range of voltages are allowable, and most of our work has been done at a current density of about 300 amp. per sq. ft. (3225 amp. per sq. m.). Cowper-Coles mentions the possibility of using galvanized "hard zinc" for anodes when making sponge zinc, as the iron is not dissolved, while the zinc is, thus lowering the operating voltage and replenishing the solution. He also recommends the use of a rotating vertical disc of a cathode, a form of cathode which we had adopted after some considerable test work. The disc can be made of iron and the upper half projects out of the electrolyte. The sponge is scraped off the disc into water as the disc slowly revolves. Rapid rotation of this disc is not allowable, as the better agitation of the electrolyte causes the formation of adherent zinc which defeats our purpose. To have a barely perceptible motion of the disc is sufficient. We had anticipated trouble in the drying of the dust, but met with none, as we found it could be heated to 250 deg. C. on the hot plate in the open air without ignition. The washing of the sponge free from the adhering solution of sodium zincate must be performed with weaker caustic, as the zincate hydrolyses in water solution to

[2] J. Chem. Met. Min. Soc., So. Africa, 7, 332 (1912).
[3] Tr. Am. Inst. Min. Eng., 52 (1915).

zinc hydrate and sodium hydrate. A water wash can follow a caustic soda wash. The dust prepared in this manner was highly efficient (over 70 per cent).

The data, obtained as a result of some of the tests performed, are summarized below.

Test 1.—50 per cent $ZnSO_4.7H_2O$ solution at 60 deg. C.; lead anode; iron cathode; current densities, 1 to 15 amp. per sq. ft. (11 to 162 amp. per sq. m.). Warty deposit. At boiling temperature a crystalline warty deposit is obtained.

Test 2.—10 per cent Zn and 1 per cent ferrous iron in sulphate solution. Current density 15 amp. per sq. ft. (162 amp. per sq. m.); voltage, 3.5. Deposit warty to loosely crystalline. Improves slightly on raising current density to 245 amp. per sq. ft. (2633 amp. per sq. m.)

Test 3.—Neutral solutions of $ZnSO_4.7H_2O$, 15 per cent. Current densities of 8 to 15 amp. per sq. ft. (86 to 162 amp. per sq. m.) A small amount of ZnO added. Anode of zinc. Result, a fair sponge.

No 1.	Fairly coarse material; precipitation efficiency	68.6%
No. 2.	Fine material; precipitation efficiency	70.1%
No. 3.	Coarse material; precipitation efficiency	64.9%
No. 4.	Coarse material; precipitation efficiency	65.6%

Test 4.—Neutral solution of zinc sulphate like above, 3 per cent Zn. The electrolysis was continued until the acidity increased to a point where the zinc became platy and coarsely crystalline. The precipitation efficiency of the zinc was 65 per cent.

Test 5.—20 per cent zinc chloride solution containing dissolved ZnO. Current density 500 amp. per sq. ft. (5375 amp. per sq. m.) Two successive samples of sponge taken. Efficiency of first test 60 per cent, of the second, 45 per cent. The sponge prepared from this solution showed a strong tendency to oxidize on drying.

Test 6.—Solution of zinc sulphate, containing 5 per cent Zn and 2 per cent sulphuric acid. Anode of "galvanizers dross." After most of the acid has been used up (during which time a fairly good smooth deposit of zinc was obtained) the deposit became spongy and the zinc dust gave a precipitation efficiency of 56 per cent.

Test 7.—Sodium zincate solution. 25 per cent caustic, 6 per cent Zn. Carbon anode. Iron cathode. Electrolyzed down to solution of 2.5 per cent Zn. Three periods of 15 minutes, during which the zinc sponge of each period was collected separately.

No.	Voltage	Current Density	Current Efficiency	Ppt. Efficiency
1	4.7	260 amps. sq. ft.	83.0%	60.5%
2	4.6	270 amps. sq. ft.	85.4	57.0
3	4.7	250 amps. sq. ft.	69.2	56.0

Test 8.—Sodium zincate solution. 22 per cent NaOH, 6 per cent Zn. Iron anode and cathode, reduced in 15 minutes to 5 per cent Zn. 4.6 volts. Current efficiency 90.7 per cent and precipitation efficiency of sponge, 65.5 per cent.

Test 9.—Sodium zincate solution. 25 per cent NaOH; 6.5 per cent Zn at beginning and 1.5 per cent at end of test. Lead anode, iron cathode. Lead anode slowly dissolved, and solution became more caustic, necessitating the addition of more zinc oxide. Three periods in test, the second starting when strong alkilinity developed.

No.	Zn.	Pb.	Eff. Pptn.
1	94.5%	4.5%	55.5%
2	79.5	16.6	39.6
3	68.5	23.6	34.7

Test 10.—Sodium zincate solution as in Test 8. Disc cathode rotation barely perceptible. Sponge of 70 per cent precipitation efficiency.

Test 11.—Sodium zincate solution. 8.9 per cent Zn at beginning and end of electrolysis. Iron disc cathode. Zinc anode. 330 amp. sq. ft. (3548 amp per sq. m.) 4.5 volts. Current efficiency, 54.2 per cent. Precipitation of dust 74.5 per cent. Analysis of dust shows 97.5 per cent Zn.

Test 12.—Sodium zincate solution 30 per cent NaOH, 8.9 per cent Zn at beginning and 3.46 per cent Zn at end of 5 hr. electrolysis at 5 volts. The electric current efficiency was determined at short intervals as follows:

Time, Min.	Current Eff.	Precip. Eff.
30	58%	74%
60	71	..
90	60	..
120	50	..
180	66	..
240	62	..
300	53	74.2

The dust on analysis showed 97.5 per cent Zn. The average current efficiency in the deposition of the zinc was about 60 per cent, and one pound of dust requires somewhat less than 3 kw. hr.

From Test 12 it can be seen that the best zinc dust was prepared from a solution containing about 30 per cent of caustic soda and saturated with zinc oxide. A high current density with the corresponding temperature seems to be the best conditions for obtaining highly efficient zinc dust. This causes a higher electric energy consumption than one might wish, but the figure of 3 kw. hr. per lb. (6.6 kw. hr. per kg.) of zinc dust is very safe in being high.

Test 9 shows the effect of the addition of lead to the zinc dust. It can be seen that the presence of much lead in the zinc dust is certainly undesirable. Zinc shavings are often given a bath of lead acetate in order to form a zinc lead couple which will be more efficient in precipitation of the precious metals. We do not know whether the lead deposited with the zinc in these tests was in the proper physical condition to allow the setting up of an electrical couple, as the appearance of the zinc dust did not give any indication of its physical condition. At any rate, over 4 per cent Pb in the zinc dust prepared by this method would seem to be detrimental to efficient precipitation. The lead anode undoubtedly dissolves as the plumbite, which is known to be soluble in caustic alkali. In case it were ever found to be desirable to have a small amount of lead in the electrolytically deposited zinc, a small auxiliary lead anode could be used of sufficient area to give the desired percentage of lead in the zinc dust.

Test 11 shows that a zinc anode can be used in order to keep the solution approximately constant in composition. In this case the arrangement serves only as a medium for transforming spelter into zinc dust. This point is of importance, as it should allow the manufacture of zinc dust at each mill from the spelter usually bought for turning into zinc shavings. It is possible that the zinc smelters could be induced to cast the zinc into anodes instead of the regular bars. It was somewhat of a surprise, however, to find no decrease in voltage where a soluble anode was used, as compared to an insoluble anode. This is possibly due to the extraordinarily high current density used.

Care of Zincate Solutions.—Some question arises as to the best way to utilize the zincate solutions in preparing zinc dust. It might be possible to treat roasted zinc ores or naturally oxidized ores with a solution of caustic alkali, leaching out the zinc as a zincate. It would also be possible to prepare the zincate from zinc oxide, purchased on the market. Since iron in the zinc oxide does not affect the properties of the zinc sponge, it might be possible to keep the solution up to strength by the addition of zinc oxide which is too contaminated with iron oxide to pass as a pigment.

The caustic solution takes up carbon dioxide from the air, forming sodium carbonate. On account of the strong solution of caustic required there is question as to the recausticizing of this solution by lime. According to Lunge,[4] the speed of the reaction between sodium carbonate and quicklime depends upon the temperature. Equilibrium is reached in 2 to 3 hr. at 108 deg. C., in 12 hr. at 80 deg. C., and more than 40 hr. at 62 deg. C. Further, in 20 per cent caustic solution the reaction comes to an equilibrium at 90 per cent completion, leaving some undecomposed carbonates in the solution. How serious this point is liable to be in practice we are unable to say.

In testing the leaching of several oxidized ores with caustic soda solutions it was found that it was very hard to get extractions of as much as 50 per cent, either by treating calcined or raw oxidized ores. It is known that ignition renders zinc oxide more difficult of solution in the caustic, but the average raw zinc "carbonate" ore will not allow of more than about 30 per cent extraction of zinc, while a calcined sample in this instance gave as high as 50 per cent extraction. Anyway, it is probable that the carbon dioxide from a zinc carbonate ore would tend toward speedy fouling of the electrolyte. Hence we do not consider as practical the proposition to make up the solutions from "carbonate" ores.

In case a spelter anode is used the question of preparation of the solution assumes small importance, and the only serious difficulty to be considered is that of fouling the solution with carbon dioxide taken up from the air. So far as our work is concerned this is still a problem.

Costs.—Due to the high consumption of electrical energy, 3 kw. hr. per lb. (6.6 kw. hr. per kg.) of zinc dust, the principal item to be considered is the cost of electric energy. The high efficiency of the zinc dust in comparison with ordinary zinc dust and the high efficiency of the latter in comparison with zinc shavings precipitation, will probably allow of considerably higher cost per pound for the new dust than for zinc shavings, or ordinary commercial zinc dust.

The high current density used allows of smaller electrolytic tank equipment than is used in most electrolytic installations. The design of a small set capable of supplying the ordinary small cyanide mill with zinc dust is hence a matter of interest. We believe that the figures presented allow of the design of such plants, but until a semi-commercial plant has been built and tested out thoroughly it is needless to present possible designs. The object of this work, as likewise of other investigation which has been conducted by the Salt Lake station of the Bureau and the Department of Metallurgical Research of the University of Utah, has been to test out various ideas and suggestions with a view of determining whether or not they possess sufficient merit to warrant their being tried out on a semi-commercial or commercial scale.

Conclusions

1. By depositing a "sponge" metal from solutions by electrolysis it is possible to get a zinc product that on drying crumbles into "zinc dust."

2. Sponge metal can be obtained from zinc sulphate solutions by the continual addition of a small amount of either copper or arsenic salts to the electrolyte. The objection to the use of zinc dust prepared by this method is the needless dilution of the bullion caused by the copper, and the danger met in the handling of gold or silver precipitates when arsenic is used to produce the sponge. These difficulties are probably not insurmountable. Fairly impure solutions can be worked only when zinc sponge is desired, and this will not handicap the ordinary electrolytic methods.

3. The preparation of zinc sponge is also possible from sulphate solutions by keeping acidity low and temperature high. Zinc oxide, rendering the solution slightly basic, is the most desirable chemical for maintaining this condition. It is subject to the objection that it is only slightly soluble in zinc sulphate solutions.

4. The same remarks apply to zinc sponge prepared from chloride solutions, except that the zinc sponge seems to be more inclined to be oxidized during drying.

5. Sodium zincate solutions allow of the deposition of zinc sponge under a widely varying range of electrical and thermal conditions. Stirring of the electrolyte must be avoided. Current efficiencies of about 60 per cent and zinc dust precipitating efficiencies of 70 to 75 per cent are possible. There seems to be no difficulty in getting 1 lb. of zinc dust from a solution of zinc, with 3 kw. hr. of energy.

6. Sodium zincate solution recommends itself because of its ease of preparation from caustic soda and zinc oxide, both of which are articles of commerce. The zinc tenor of the solution can be maintained either by the addition of more zinc oxide or by the use of zinc anodes, by which latter process spelter can be converted into zinc dust.

[4] Lunge, Sulphuric Acid and Alkali, vol. 2, 806.

The Constitution of Liquids with Especial Reference to Surface Tension Phenomena*

By Irving Langmuir

The epoch-making work of Laue and Bragg has given us a clear insight into the structure of crystalline bodies. In the case of inorganic crystalline substances, it has been found that the atoms are arranged according to definite lattices so that certain groups of atoms are repeated in a regular manner. In this arrangement, however, there is nothing to indicate where one group ends and the next begins. Thus, in a crystal of common salt, the chlorine and sodium atoms alternate in regular order, but are not grouped together into pairs. Any division of the crystal into molecules is thus purely arbitrary. We must therefore conclude that solid bodies are not built up of molecules, but of atoms arranged in definite ways; or rather, we should regard a crystal as a single large molecule.

From this viewpoint the forces holding solid bodies together (cohesion, etc.) are chemical forces, and phenomena such as evaporation are strictly chemical phenomena. So far, in the study of crystal structure, only inorganic bodies have been investigated. It is certain that in solid organic bodies the atoms are arranged in groups which are usually identical with the molecules found when the substances exist as vapors. We may call these *group molecules*. There are good reasons for believing that in crystals of an organic substance these group molecules are held together by chemical forces (secondary valence) to form single large molecules.

A similar theory is now proposed for the structure of liquids. Each atom in a liquid is regarded as being chemically combined with all adjacent atoms. This chemical union may in general be of two kinds, characterized by *primary* and *secondary* valences. The atoms held together by primary valence usually constitute *group molecules*, in which the atoms are more or less rigidly attached to each other in definite arrangements. The secondary valence serves to hold the group molecules together. In very many cases (such as most in-

*An abstract of a paper read at the New York City meeting of the American Chemical Society, September, 1916, in The Symposium on Colloids.

organic liquids) the group molecules are very much simpler than the usual "chemical molecules" and may often be entirely absent. Thus, in such substances as water, concentrated sulphuric acid or in molten salts or metals, there are probably no group molecules at all; the atoms being held together by secondary valences.

A drop of liquid is thus regarded as a single large molecule. In fact, the whole earth, including the oceans (but excluding the atmosphere) may be looked upon as a single molecule.

The most essential difference between liquids and solids is the mobility of the former. The chemist is already familiar with a mobility between different parts of a molecule and has given the name tautomerism to this phenomenon. The mobility of liquids is therefore a result of tautomeric re-arrangements of the atoms.

Evaporation, condensation, freezing, melting, solution, adsorption, and surface tension, and even viscosity, are thus chemical phenomena, and chemical knowledge already available may be directly applied in their study.

This theory has been applied with marked success in the study of the adsorption of gases by solids. Adsorbed gases are regarded as being chemically combined (either primary or secondary valence) with the *atoms* forming the surface of the solid. The adsorbed film thus usually consists of a *single* layer of atoms or group molecules, which forms a continuation of the structure of the solid. The effect of such films on the catalytic activity of surfaces (as, for example, platinum) depends entirely upon the nature and the arrangement of the atoms forming the actual surface of the solid.

In a similar way a theory of surface tension is now proposed in which the structure of the *surface layer of atoms* is regarded as the principal factor in determining the surface tension (or rather surface energy) of liquids. This theory is supported in the most remarkable way by all available published data on the surface tension of organic liquids.

According to this theory, the group molecules of organic liquids arrange themselves in the surface layer in such a way that their active portions are drawn inwards, leaving the least active portion of the molecule to form the surface layer. By "active portion" of a molecule is meant a portion which is characterized by a strong stray field (residual valence). Chemical action may be assumed to be due to the presence of electromagnetic fields surrounding atoms. Surface tension (or surface energy) is thus a measure of the potential energy of the electromagnetic stray field which extends out from the surface layer of atoms. The molecules in the surface layer of the liquid arrange themselves so that this stray field is a minimum.

The surface energy of a liquid is thus not a property of the group molecules, but depends only on the *least active portions of the molecules* and on the manner in which these are able to arrange themselves in the surface layer.

In liquid hydrocarbons of the paraffin series, the molecules arrange themselves so that the methyl groups (CH_3) at the ends of the hydrocarbon chains form the surface layer. The surface layer is thus the same, no matter how long the hydrocarbon chain may be. As a matter of fact, the surface energy of all these many different substances from hexane to molten paraffin, have substantially the same surface energy—namely, 46 to 48 ergs per square centimeter, although the molecular weights differ very greatly.

If, now, we consider the alcohols such as CH_3OH, C_2H_5OH, etc., we find that their *surface energies* are *practically identical with those of the hydrocarbons.* The reason for this is that the surface layer in both cases consists of CH_3 groups.

With such substances as CH_3NO_2, CH_3I, we find that the surface energy is much greater than that of the hydrocarbons. This is due to the fact that the volume of the I or the NO_2 is so great that the surface cannot be completely covered by the CH_3 radicals. The forcing apart of these groups increases the surface energy.

Particularly interesting relations are found with benzol derivatives.

In benzol itself, the group molecules arrange themselves so that the benzol rings lie flat on the surface, since the flat sides of these rings are the less active portions of the molecules. The surface energy of benzol is about 65 ergs per square centimeter.

If, now, an active group, such as OH, is substituted for one of the hydrogens in the benzol (forming phenol or carbolic acid), this group is drawn into the body of the liquid, *tilting the benzol ring up on edge* and raising the surface energy to about 75 ergs per square centimeter, which corresponds to the activity of the perimeter of the benzol ring. Thus *any active group* strong enough to tilt the ring up on edge raises the surface energy to about 75. Two active groups side by side (ortho position) have no greater effect than one. But two active groups opposite one another (para position) cannot both go wholly below the surface, so that the surface energy then becomes abnormally large (about 85 in case of para nitrophenol). The substitution of methyl or ethyl groups in the benzol ring lowers the surface energy except where an active group in an adjacent position draws these groups below the surface.

Some of the best evidenec in support of the new theory is derived from experiments on thin films of oil on water or mercury. Oleic acid on water forms a film one molecule deep, in which the hydrocarbon chains stand vertically on the water surface with the COOH groups in contact with the water.

Acetic acid is readily soluble in water because the COOH group has a strong secondary valence by which it combines with water. Oleic acid is not soluble because the affinity of the hydrocarbon chains for water is less than their affinity for each other. When oleic acid is placed on water the acid spreads upon the water because by so doing the *COOH can dissolve in the water* without separating the hydrocarbon chains from each other.

When the surface on which the acid spreads is sufficiently large, the double bond in the hydrocarbon chain is also drawn down on to the water surface, so that the area occupied is much greater than in the case of the saturated fatty acids.

Oils which do not contain active groups, as for example pure paraffin oil, do not spread upon the surface of water.

The measurement of the area of water or mercury which can be completely covered by a given amount of a substance affords an accurate method of determining the shapes of group molecules. Thus it is found that the molecules of stearic acid on a surface of water have a length of about 23 x 10^{-8} cm. and cover an area of 24 x 10^{-16} sq. cm. These measurements prove that the molecules are not spherical but are much elongated.

This theory also affords an explanation of the mechanism by which colloids are formed. If a film of closely packed oleic acid molecules covers the surface of water to which sodium hydroxide has been added, OH groups are adsorbed by the COOH radicals, causing an expansion of the lower side of the film without a corresponding expansion of the upper side. This results in the bulging of the film downwards in spots so that

it finally detaches itself in the form of particles, the outer surfaces of which consist of COOH groups together with the adsorbed OH, while the interior consists of the long hydrocarbon chains.

The size of the colloidal particles is determined by the difference in size between the two ends of the molecules just as the size of an arch is dependent upon the relative sizes of the two ends of the stones of which the arch is constructed.

In the final publication of this paper the bearing of the shapes of molecules on the formation of colloids will be discussed in detail.

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Coal and Coke By-Products as a Source of Fixed Nitrogen*

By Horace C. Porter

My purpose in addressing you on the subject of fixed nitrogen from coal carbonization is to call attention to the present remarkable growth of by-product coke making in this country, and to dispel if possible certain illusions relative to this industry. The supply of fixed nitrogen from coal now available as a by-product of coke and gas making is much larger than is generally realized and its importance has in some quarters been unduly depreciated.

In order to drive home in the beginning the principal point of this paper, attention is to be drawn especially now to one actual figure, illustrating in forceful manner the relation of coke by-products' growth to preparedness.

The increase in capacity for ammonia production at by-product coke plants due to new establishments now building and those put into operation in 1916 amounts to 46,400 tons of ammonia (NH_3) per year. Taken together with the present producing capacity of gas works other than coke ovens (the equivalent of 12,500 tons of ammonia per year), this increase in capacity more than meets the Government's estimate of the requirement of the United States for fixed nitrogen for munitions of war. In other words the producing capacity of coke ovens as it stood in 1915, need not be touched for this emergency; the assured increase in 1916 and 1917 will in itself provide an adequate nitric acid supply for war needs.

From the curves in Fig. 1 may be seen the rapidity of the increase in the last few years. In the four years from 1914 to 1918, 56,000 tons will have been added to the producing capacity of coke ovens, an amount nearly equal to the entire previous growth of the industry during the twenty years of its history in this country.

The Problem of Nitrogen Preparedness

The sustaining of life on the earth depends upon the absorbable nitrogen in plant foods; the destruction of life in war requires the use of fixed nitrogen in explosives. For plant life nitrogen in combined form is essential and must be artificially supplied in many localities; for all known military explosives, nitrogen in the form of nitrates or nitric acid, is absolutely indispensable.

The nation, therefore, has become aroused naturally and rightly to an intense interest in the question of nitrogen supply. The great European war and a realization of America's lack of military preparedness are largely responsible for this interest at the present time.

In view of recent legislation by Congress providing for investigation of this matter and eventually for the building of a Government nitrate plant, it is well now

*A paper read at the New York City meeting of the American Chemical Society.

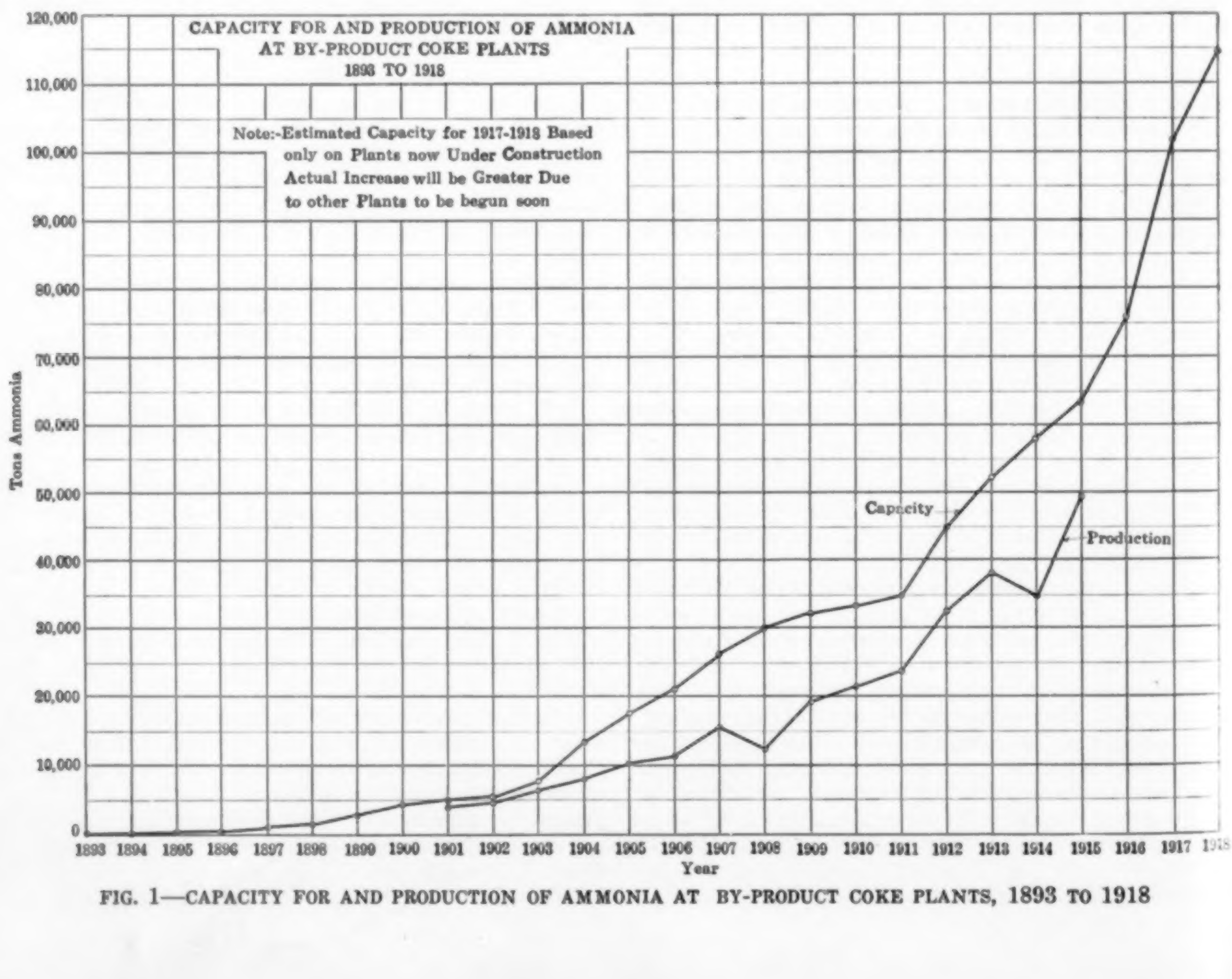


FIG. 1—CAPACITY FOR AND PRODUCTION OF AMMONIA AT BY-PRODUCT COKE PLANTS, 1893 TO 1918

to take account of stock and let the nation be informed as to its present resources in fixed nitrogen, particularly in those obtainable from coal.

We have need of correct and authoritative information on this subject, for a great deal of misleading and unfortunate misinformation has been put before the public within recent months, much of it no doubt unintentional and due to ignorance.

Ammonia is the most available source of nitric acid when Chili saltpeter is not at hand. The contact process of oxidation of ammonia has been put on a practical manufacturing basis and on an immense scale in Germany. Experiments in our own country have gone far enough to prove it feasible for emergency use. Other sources of nitric acid are more costly and more cumbersome.

As to the source of the ammonia, it does not matter much from a technical point of view what source is used. In Europe, both the by-product ammonia from coal and the ammonia produced from cyanamide have been used. No doubt the synthetic ammonia of the Haber process is equally good. The ammonia, from whatever source, must be purified from sulphur and carbonic acid as in some of the contact processes, at least, these substances tend to poison the contact material, but small amounts of volatile organic substances are not harmful. The question is then, Is our present and our prospective supply of ammonia adequate for nitric acid manufacture in an emergency of war?

Statistics of By-Product Ammonia Supply

The distillation of coal in by-product coke ovens and in gas works in the United States produces to-day at maximum capacities, 88,500 tons of ammonia per annum. The increase in capacity which will be added to this during 1916 and 1917 by plants now under construction will be at least 38,000 tons. The Government's recent appropriation of $20,000,000 if devoted to an atmospheric fixation plant by the cyanamide process, and the necessary accompanying water power plant will have a capacity in ammonia equivalent, considerably less than this latter figure, *i.e.*, less than the by-product ovens are adding to their capacity in two years. This is based on published estimates made in connection with the hearings on the nitrate bill.

The total capacity for by-product ammonia in this country will by the close of 1917 be at least 126,500 tons as NH_3. This will be capable of producing 404,000 tons of 95 per cent nitric acid.

In Table 1 are arranged the by-product coke plants of the country with their coal consumption and ammonia producing capacities. Inasmuch as ammonia liquor is a more ready form for conversion into nitric acid than is ammonium sulphate, it may be noted that the coke plants of the country are so equipped that between 35 per cent and 40 per cent of their total ammonia capacity can be produced as liquor. It is to be borne in mind also that all plants producing sulphate produce about 25 per cent of their total ammonia in the intermediate stage of weak liquor and could quickly and easily be modified so as to place their product on the market as strong ammonia liquor, in that proportion.

By-product coke ovens can now produce a total of 75,950 tons of ammonia. Within eighteen months there will be about 38,000 tons added to this, or an increase of 50 per cent. The gas works of the country produce about 12,500 tons more, practically all in the form of liquor. The grand total of capacity at both gas works and coke ovens is 126,500 tons, of which somewhat over one-third is new, being added during the years 1916-1917.

If the United States consumption of ammonia for all purposes in 1915, viz., 70,000 tons, is subtracted from this increased total capacity and the balance, 56,500 tons—the surplus of 1918 capacity over 1915 consump-

FIG. 2—BY-PRODUCT COKE PLANTS IN THE UNITED STATES (SEPT. 1, 1916)

Plants indicated by circles with black in the center produce ammonium sulphate. Plants indicated by circles with white inside produce ammonia liquor. Scaled according to capacity.

tion—is then converted to nitric acid, it will produce 181,000 tons of 95 per cent acid or more than the estimated requirement for a war emergency. In addition to this a large amount of ammonia could, in the event of war, be temporarily diverted from its usual disposal as fertilizer.

The distribution of these coke oven ammonia plants over the country is a matter of large importance in connection with the problem of transportation to proposed plants using the ammonia. The map (Fig. 2) shows the location of these plants, with a rough indication of their size.

The Nitrogen Reserves

The reserves of minable coal in the United States are estimated by M. R. Campbell of the United States Geological Survey at 3540 billions of tons. Of this amount, by present methods of mining, probably 2360 billion tons can be brought to the surface. If the average nitrogen content in this coal is 1.3 per cent we have in our recoverable coal a reserve of nearly 31 billion tons of nitrogen. Part of this immense nitrogen reserve, unfortunately, is being wasted through the common methods of utilizing coal by combustion, and, by non-recovery coking. We mined bituminous coal in 1915 containing 6,000,000 tons of nitrogen, and of this 1,000,000 tons could have been recovered if all the coal had been treated in modern coke ovens or by-product gas producers. We actually recovered in by-product ammonia in 1915, about 51,000 tons of nitrogen.

About 9/10 of 1 per cent therefore of the coal nitrogen which was mined in 1915 was utilized. In 1918 possibly double that amount will be saved. Five per cent of what was mined would easily take care of the country's demands for ammonia and nitrates for many years.

The coal actually made into coke and gas in 1915 would have yielded 135,000 tons of nitrogen in the form of by-product ammonia if it had all been coked with by-product recovery. This would have approximately equalled the amount of fixed nitrogen actually used in the United States in 1915 other than that in the organic ammoniates such as packing-house wastes, and that in munitions sent abroad, that is, between 125,000 and 150,000 tons.

At the rate at which our coal is now being mined, the nitrogen reserves would be exhausted in 6000 years. Less than 10 per cent of the coal mined is being treated for recovery of its nitrogen and we have room therefore greatly to expand this recovery without increasing the rate of exhaustion of our reserves.

The coal by-product nitrogen, to be sure, cannot be practically recovered to any greater extent than conforms to proper utilization of the accompanying products, coke, tar, gas and gas-power. But this utilization is rapidly growing and even at the minimum rate of production and utilization of coke in this country in recent years, the corresponding fixed nitrogen recovery (say 125,000 tons), would amply provide for the country's needs in an emergency of war.

The Distribution of By-Product Ammonia in an Emergency of War

It is important to consider whether a sufficient amount of by-product ammonia can be spared from its regular channels of disposal to take care of the needs of a war emergency.

As has been shown above, the increase alone in by-product ammonia production in 1916-1917 will make more than enough nitric acid to supply war needs. If, however, it should be found necessary to use more than this in order to supply other demands for nitrates or nitric acid there would be no hardship or difficulty in diverting, for the temporary need, a large part of the present production of ammonia from its normal uses.

Fertilizer, in America, is not indispensable for maintaining our home consumption of food crops. Let us not be misunderstood in this statement. The use of fertilizer is by all means to be encouraged. Far be it from anyone to depreciate the need of its increased use in this country. If we will improve our crop yields per acre and raise our efficiency in agriculture to a par with that of most other countries we must, among other things, use more fertilizer.

However, it can hardly be questioned that as a temporary expedient in an emergency of war, we could, without jeopardy to our food supply or the national welfare, divert 75 per cent of the 160,000 tons of ammonium sulphate now devoted annually to fertilizer purposes, and use it for nitric acid manufacture. Giving up also the 200,000 or 250,000 tons of nitrate used as fertilizer, we should still have available the abundant supply of organic ammoniates, tankage, bone, blood, cottonseed meal, etc., of which the consumption was about 2,000,000 tons in 1915.

The country's needs for refrigeration, which are stated authoritatively to be about 4000 tons of ammonia annually or under 5 per cent of the present ammonia-producing capacity, it is true, could not be diverted to other use, nor could the ammonia devoted to ammonium nitrate in military explosives. These uses, however, are small as compared to that of ammonium sulphate as fertilizer, and would not need to be invaded in order to provide for nitric acid manufacture.

If 57,000 tons of ammonia should be used to meet the Government's estimated need of 180,000 tons of nitric acid, and say 30,000 tons more of ammonia for other nitric acid, there would still remain, of our 127,000 tons of by-product ammonia, a balance of 40,000 tons to meet the requirements of industries. In 1915 about 26,000 tons were used for purposes other than as fertilizer.

Prospect of Future Growth

The above-named facts and figures presented in behalf of by-product ammonia are based only on the assured capacity of existing plants and of those under construction. It has been shown that the needs of the country in fixed nitrogen in an emergency of war can be met with this assured ammonia capacity. The industry, however, may look forward to a still larger growth.

The total coke consumed in the United States in 1915 was about three times what was produced in by-product ovens. The estimated capacity of by-product ovens for the year 1918, as given in the accompanying table, based on plants now under construction, is probably less than 55 per cent of the total coke which will be made in that year. By-product coking therefore has room to grow—it can almost double the capacity shown by plants now built or building before it will meet the country's present requirement in coke.

The present coke requirements are destined also to grow. The growth of coke by-products recovery is not limited, as many have claimed, to the demands of the steel industry. The sale and use of "domestic coke," *i.e.*, all coke used for fuel purposes other than metallurgical, is rapidly expanding in this country. An amount not far from 2,000,000 tons was sold in the United States in 1915 and records of recent years show an annual growth of sales in many communities of about 30 per cent.

Recovery of Ammonia by Gas Producers

By-product gas producers afford another source of ammonia from coal, supplementing the coke ovens and

gas retorts. These producers offer immense possibilities for the future, since they can utilize non-coking and inferior coals, lignites, and the coal wastes obtained in mining and in coal washing.

Their yield of ammonia per ton of coal is large, viz., 15 to 18 lb. as NH_3 and their gas can be utilized for power in gas engines. These producers have had a large development in recent years in Germany and England and it is claimed that very cheap power is being made by them.

TABLE I

BY PRODUCT COKE PLANTS IN THE UNITED STATES, SEPTEMBER, 1916

Their Capacities for Coal Consumption and Ammonia Production

COMPLETED PLANTS

Owner or Operator	Location	No. of Ovens	Kind of Ovens	Annual Capacity (Net Tons)		
				Coal	Total Coke	Ammonia (as NH_3)
Allegheny By-Product Coke Co.	Glassport, Pa.	120	Otto	260,000	195,000	650
Cambria Steel Co.	Johnstown, Pa.	462	343 Otto, 92 Koppers, 27 Gas-Machinery	1,530,000	1,224,000	3,442
Carnegie Steel Co.	Farrell, Pa.	212	Otto	830,000	581,000	2,283
Dunbar Furnace Co.	Dunbar, Pa.	110	Semet-Solvay	248,000	173,600	682
Lehigh Coke Co.	S. Bethlehem, Pa.	424	Koppers	2,400,000	1,920,000	5,400
Lackawanna Iron & Steel Co.	Lebanon, Pa.	228	Otto	500,000	360,000	1,250
Pennsylvania Steel Co.	Lebanon, Pa.	90	Semet-Solvay	387,000	278,600	1,017
Pennsylvania Steel Co.	Steelton, Pa.	120	Semet-Solvay	516,000	371,500	1,354
Phila. Suburban Gas & Elec. Co.	Chester, Pa.	40	Semet-Solvay	125,000	87,500	313
Camden Coke Co.	Camden, N. J.	150	Otto	360,000	252,000	990
Empire Coal & Coke Co.	Geneva, N. Y.	46	Semet-Solvay	146,000	102,200	401
Lackawanna Iron & Steel Co.	Buffalo, N. Y.	469	188 Otto, 281 Rothberg	1,350,000	972,000	3,375
The Solvay Process Co.	Syracuse, N. Y.	40	Semet-Solvay	65,000	45,500	195
New England Gas & Coke Co.	Everett, Mass.	400	Otto	650,000	455,000	1,950
Maryland Steel Co.	Sparrows Point, Md.	120	Koppers	730,000	525,600	1,825
National Tube Co.	Benwood, W. Va.	120	Semet-Solvay	270,000	189,000	743
Laclede Gas Light Co.	St. Louis, Mo.	56	Koppers	320,000	240,000	880
Minnesota Steel Co.	Duluth, Minn.	90	Koppers	600,000	450,000	1,500
Zenith Furnace Co.	Duluth, Minn.	65	Otto	160,000	112,000	440
Cleveland Furnace Co.	Cleveland, Ohio	100	Semet-Solvay	450,000	337,500	1,125
Republic Iron & Steel Co.	Youngstown, Ohio	143	Koppers	1,020,000	744,600	2,805
Youngstown Sheet & Tube Co.	Youngstown, Ohio	204	Koppers	1,300,000	919,000	3,575
Toledo Furnace Co.	Toledo, Ohio	94	Koppers	560,000	408,800	1,540
United Furnace Co.	Canton, Ohio	47	Koppers	280,000	204,400	770
Hamilton Otto Coke Co.	Hamilton, Ohio	100	Otto	240,000	168,000	720
Milwaukee Coke & Gas Co.	Milwaukee, Wis.	160	Semet-Solvay	732,000	549,000	2,104
Northwestern Iron Co.	Mayville, Wis.	36	Otto	160,000	115,200	400
Citizens Gas Co. (1)	Indianapolis, Ind.	41	Semet-Solvay	330,000	237,600	908
Citizens Gas Co. (2)	Indianapolis, Ind.	100	Otto	320,000	230,400	880
Illinois Steel Co.	Gary, Ind.	560	Koppers	3,600,000	2,880,000	7,650
Central Indiana Gas Co.	Muncie, Ind.	22	Klonne	40,000	28,000	100
Inland Steel Co.	Indiana Harbor, Ind.	86	Koppers	585,000	438,800	1,535
By-Products Coke Corporation	So. Chicago, Ill.	280	Semet-Solvay	1,300,000	975,000	3,575
North Shore Suburban Gas Co.	Waukegan, Ill.	13	Semet-Solvay	55,000	38,500	165
Coal Products Mfg. Co.	Joliet, Ill.	53	35 Koppers, 18 Wilputte	340,000	238,000	1,020
Illinois Steel Co.	Joliet, Ill.	280	Koppers	1,500,000	1,200,000	3,375
The Solvay Process Co.	Detroit, Mich.	175	Semet-Solvay	1,150,000	862,500	3,163
Michigan Alkali Co.	Wyandotte, Mich.	30	Otto	94,000	65,800	235
Kentucky Solvay Co.	Ashland, Ky.	103	Semet-Solvay	800,000	600,000	2,400
Chattanooga Gas & Coal Pro. Co.	Chattanooga, Tenn.	12	Roberts	74,000	51,800	185
Woodward Iron Co.	Woodward, Ala.	170	Koppers	970,000	737,200	2,207
Tenn. Coal I. & R. R. Co.	Fairfield, Ala.	280	Koppers	1,650,000	1,254,000	4,538
Tenn. Coal I. & R. R. Co.	Ensley, Ala.	240	Semet-Solvay	540,000	410,400	1,485
Central Iron & Coal Co.	Holt, Ala.	60	Semet-Solvay	290,000	220,400	800
Totals, completed plants		6756		29,827,000	22,479,400	75,950

PLANTS BUILDING

Owner or Operator	Location	No. of Ovens	Kind of Ovens	Annual Capacity (Net Tons)		
				Coal	Total Coke	Ammonia (as NH_3)
Northwestern Iron Co. (2d Bat'y)	Mayville, Wis.	36	Otto	160,000	115,200	400
Carnegie Steel Co.	Clairton, Pa.	640	Koppers	3,960,000	2,851,000	10,890
Seaboard By-Product Coke Co.	Jersey City, N. J.	110	Koppers	681,000	510,700	1,874
Wickwire Steel Co.	Buffalo, N. Y.	60	Semet-Solvay	386,000	289,500	965
Bethlehem Steel Co. (3d, 4th, 5th and 6th Batteries)	Sparrows Pt., Md.	240	Koppers	1,500,000	1,125,000	3,750
La Belle Iron Works	Follansbee, W. Va.	94	Koppers	610,000	445,300	1,677
Minnesota By-Product Coke Co.	St. Paul, Minn.	65	Koppers	380,000	273,600	1,140
River Furnace Co.	Cleveland, Ohio	204	Koppers	1,300,000	949,000	3,575
Brier Hill Steel Co.	Youngstown, Ohio	84	Koppers	520,000	379,600	1,430
American Steel & Wire Co.	Cleveland, Ohio	180	Koppers	1,150,000	839,500	3,162
National Tube Co.	Lorain, Ohio	208	Koppers	1,320,000	963,600	3,630
Dover By-Product Coke Co.	Canal Dover, Ohio	24	Roberts	120,000	87,600	300
Inland Steel Co. (3d Battery)	Indiana Harbor, Ind.	44	Koppers	305,000	228,800	801
Indiana Coke & Gas Co.	Terre Haute, Ind.	30	Gas-Machinery	150,000	105,000	450
Gulf States Steel Co.	Gadsden, Ala.	37	Koppers	230,000	174,800	575
Colorado Fuel & Iron Co.	Pueblo, Colo.	120	Koppers	720,000	518,400	2,160
Bethlehem Steel Co.	Steelton, Pa.	60	Koppers	375,000	270,000	1,031
Totals, plants building		2236		13,867,000	10,126,600	37,810
Totals, completed plants		6756		29,827,000	22,479,400	75,950
Grand totals, for all plants		8992		43,694,000	32,606,000	113,760

	Tons NH_3
Annual capacity for ammonia at coke plants	113,760
Annual capacity for ammonia at gas works	12,500
Total annual capacity of coal carbonizing plants	126,260
Practical yield of 95 per cent nitric acid from this amount of ammonia (126,260 tons)	404,000 tons
Total consumption ammonia in U. S. in 1915	70,000 tons NH_3
AMMONIA CAPACITY (AT CLOSE OF 1917) IN EXCESS OF THAT NECESSARY TO MAKE 180,000 TONS 95 PER CENT NITRIC ACID	70,100 tons NH_3

Germany's Situation Compared to that of America

Germany, when the war began, had to provide for immense new supplies of fixed nitrogen. Chilean nitrate was cut off, by-product ammonia had reached almost its limit of production, (the coke consumption of the country being all from by-product ovens), and finally, to cope with the enemy blockade of foodstuffs, the soil had to have nitrogenous fertilizer in undiminished quantity. There was no recourse except atmospheric fixation. Germany met the situation and, by a remarkable development of fixation processes has in two years built up a nitrogen industry from about 22,000 tons a year to about 140,000 tons, not including by-product ammonia. All credit be given her for this achievement.

America, on the other hand, uses for food crops very little fertilizer and would be in no degree dependent on it for maintenance of food supply in war. In this country, also, unlike Germany, the production of by-product ammonia is capable of a very large increase without causing an over-production of coke since half of our coke or more is now made without by-product recovery. This increase in fact, is rapidly being accomplished at the present time.

America can spare her by-product ammonia, temporarily, from its use as fertilizer. Germany can not. Ammonium sulphate, or by-product ammonia, furnishes in America less than one-fourth of the total nitrogen used in fertilizers.

The fixation of atmospheric nitrogen will come sooner or later in America. It will be welcomed as a valuable supplementary source of fixed nitrogen independent of foreign importation. We shall have it established in fair competition with existing industries, when, without Government subsidy but with proper water power legislation, it shall find low enough power costs to enable it to make and sell fixed nitrogen products at a profit.

We have shown that the supply of fixed nitrogen in this country from coal by-products is great enough to take care of estimated war needs and the latter therefore, cannot be urged as an excuse for a Government subsidy to the atmospheric nitrogen fixation industry.

The Government's Action

Now what has been done by our last Congress on this question, and what is the possible effect of its action?

An appropriation was made of $20,000,000 to build a nitrate plant to be owned and operated by the Government. The act making this provision is a military measure, Section 124 of H. R., 12766, "An Act to Increase the Efficiency of the Military Establishment of the United States." The plant may be operated in time of peace and sell its product. In other words it is a Government ownership project, which may result in Government competition with private enterprise in time of peace. In the face of the fact that we have already an adequate supply of ammonia for war needs, Congress has provided for an expensive establishment to insure such a supply, and opened the way for Government operation of this establishment as a competitor for private trade.

Here we must call attention to the fact that the by-product coking and gas industries afford our only source of benzol, toluol and coal tar products. The present capacity of these industries would not give the nation all the toluol it should have for war needs in the manufacture of explosives. In spite of the fact that Great Britain and France have large coal by-products industries and that the present large production of toluol in America is being in great measure sent abroad, the present abnormal market price which toluol commands in this country shows that the demand is far greater than the supply. So important to military preparedness is a maximum supply of coke by-products that the Government should run no risk of a set back to this industry until all of the coke shall be made with by-product recovery.

If the Governmental authorities which now have the nitrate problem in hand shall so interpret and apply this legislation of Congress as to permit Governmental competition in time of peace with present producers of ammonia, the expansion of by-product coking in this country will be endangered. When by-products do not command good prices the American manufacturer does not easily turn from the simple bee hive coking to the more elaborate by-product ovens. Conservation and industrial advancement in America are involved seriously in the decision to be made.

It is claimed for this bill that its virtue lies in benefitting the farmer by lowering the cost of his fertilizer. The producer's price of nitrogenous fertilizer in this country has not been greater than in other countries. This can be verified by published quotations. The farmer has to pay more for his fertilizer in the United States than he does in Belgium or in Germany because of higher transportation costs and other factors over which the producer has no control. It is now proposed, however, by advocates of Governmental fertilizer manufacture, that the present producers of ammonia shall bear the burden of a reduction in cost to the farmer, place their prices below those of European countries, and thus allow the expansion of large and important industries, essential to the national welfare, to be retarded. Investigation is now being made by Governmental boards, to determine, before the nitrate plant is built what shall be the process to be used therein. These investigating boards are fully informed as to the large and growing supply of by-product ammonia and are making their inquiries accordingly.

Methods of Recovery of Fixed Nitrogen as a By-Product of Coal Carbonization

The ammonia carried in the gases from coke ovens or gas retorts is partly in combined form as chloride, sulphate, cyanide, etc., and partly free or loosely combined as carbonate, hydrosulphide, etc. Since the raw gases always contain water as a product of the decomposition of the coal, an aqueous condensate forms in the gas mains and the large gas coolers. This condensate carries a large part of the combined ammonia and some of the free. It is a weak solution of ammonia varying in strength generally from 0.2 to 1.0 per cent NH_3. In all plants whether they make sulphate of ammonia by the "direct process" or ammonia liquor by washing the gas, this condensate in the mains and coolers is obtained, and constitutes 20-30 per cent of the total ammonia.

In the "direct process" for ammonia recovery, the gas after being freed from tar passes directly into sulphuric acid in lead-lined saturators, arranged for continuous operation. The Koppers direct process, by use of reheaters for the gas, maintains temperatures in the gas and in the saturator such that an excellent quality of well crystallized sulphate forms and the bath is kept at constant strength. Condensation in the saturator is effectually prevented.

At plants where all of the ammonia is made into liquor a gas washing system is used, whereby the gas is thoroughly washed with cold water in suitable scrubbing towers. These are either of the "bell" type consisting of a series of superimposed rings in each of which the gas passes from under a bell through circulating water or of the simpler "grid" type in which water flows downward in the tower over grids which offer large surface to the gas for the absorption of its ammonia. The

weak aqueous liquor thus produced is distilled and concentrated by steam in special column stills, continuously operated, and requiring very little operating labor. The so-called "lime leg" takes the residue from the free ammonia still, and distills it with milk of lime.

For making purified liquor or aqua ammonia these stills are elaborated by the addition of more rings and dephlegmating sections; hydrogen sulphide and carbonic acid are eliminated by utilizing the great difference of solubility between these gases and ammonia gas in water or weak ammonia solution. Pyridene and traces of organic matter or of tars are removed by oil or charcoal washers. In some plants the last traces of Co_2 and S are removed by lime or alkali washers.

Aqua ammonia is being made at a number of plants in the United States by this continuous distillation method, so as to be practically free of carbonic acid and hydrogen sulphide. The costs of purification in this manner are low.

By-Product Ammonia for Nitric Acid Manufacture

Now, in case a question may be raised as to the suitability of by-product ammonia for use in a contact process of nitric acid manufacture, I will merely say that many evidences are at hand to show that this ammonia has been used successfully abroad for such processes on a commercial scale, and preliminary experiments in this country on a small scale show that the process works well with by-product ammonia and gives a conversion of 90 per cent or higher.

An article by Schüphaus in "Metall und Erz," Vol. 13 (1916), p. 21, describes the practical operation of a plant making nitric acid by the Ostwald process and using crude ammonia liquor for the raw material. No difficulties likely to arise with this raw material are mentioned.*

Hilgenstock, a high authority on ammonia and its production, published an article in the German "Journal für Gasbeleuchtung," Nov. 27, 1915, on the methods of concentrating and purifying ammonia liquor from gas and coke plants. He states, "On account of the large demands of the war operations for ammonia, this production of concentrated liquor and of pure aqua ammonia has lately come to the forefront again."

A prospectus issued in 1913 by the English "Nitrogen Products and Carbide Co., Ltd.," and abstracted in *Iron & Coal Trades Review*, Vol. 86 (1913), page 837, states that in the contact process which they will use to make nitric acid from ammonia "it does not matter much from a technical point of view what source is used for the supply of ammonia." . . . "The ammonia plant . . . sends out nearly pure, dry, ammonia gas freed from CO_2 and H_2S. The gas is not freed from traces of organic materials which may come over with it for these impurities have been shown to exert no harmful influences on the process."

Further references of this kind showing the use of by-product ammonia in these processes might be cited. There appears to be nothing in the technical literature showing that such use has been found impracticable. The process has not been placed on a commercial footing in the United States and is only in the experimental stage in this country.

H. Koppers Co.,
Pittsburgh, Pa.

Economizers.—The B. F. Sturtevant Company, Boston, Mass., has issued a new publication, Bulletin 222, describing economizers in the power plants of paper mills. The booklet contains several illustrations of installations of Sturtevant economizers in paper mills and a discussion of the value of this appliance.

*The essential features of this article were published in this Journal, April 15, 1916.—EDITOR.

New York Meeting of American Electrochemical Society

Report of Concluding Sessions

An account of the two first sessions of the meeting held by the American Electrochemical Society during the last days of September in New York City in conjunction with the Second National Exposition of Chemical Industries was given in our last issue (page 381). A report of the two concluding sessions follows:

Thursday Afternoon Session

The Thursday (Sept. 28) afternoon session, held at the Hotel Astor, was devoted to the reading and discussion of papers on electro-metallurgical subjects.

The Protection of Iron by Electroplating

The protection of iron by electroplating was the subject of a paper of Prof. OLIVER P. WATTS of the University of Wisconsin and Paul L. DeVerter. The results are given of a series of experiments carried out at the Laboratory of Applied Electrochemistry of the University of Wisconsin, to determine the porosity of electroplating on iron, and to determine the protection afforded by different metals. It was thought that the superior protection afforded to iron by electrogalvanizing indicated either that the zinc deposits were less porous than those of other metals, or that in the thickness used commercially all electrodeposits are porous, and that the protective action of zinc was due to its being electropositive to iron.

The experiments confirmed the view that the protection was due to galvanic action.

(1) It was found that thin electrodeposits of zinc, copper, nickel and brass are full of holes, and therefore only the first may be relied on to prevent rusting, unless deposits are made much heavier than is at present the rule.

(2) Deposits of nickel should exceed 0.0015 in. (0.038 mm.) in thickness in order to protect iron out of doors, and copper or brass plate should have three times this thickness. Even then it is a question how long such coatings will afford protection.

(3) For the protection by electroplating of iron which is to be exposed to the weather, zinc (or cadmium) is the only metal worthy of consideration.

(4) The experiments do not show that double coatings—zinc followed by copper or brass—are distinctly superior to a single heavy coating of the latter metals. If zinc is to be used advantageously, it should form the outer coating.

(5) The authors think it very desirable that some method be found for producing a uniform electroplate, free from the holes which were responsible for rusting in these experiments. Could such plating be done deposits of nickel, copper and brass would form a far more effective protection to iron than at present.

In the discussion which followed Mr. Hogaboom referred to conclusion (2) and said that his experience from practice is in accord with Watts' conclusions. The subject is of vital importance for the industry.

Dr. Hering spoke of pinholes. Suspended foreign particles in the solution may be carried over to the cathode and be deposited with the metal. This may often account for the pinholes. The use of a diphragm might hold such foreign particles back. With respect to pickling, electrolytic pickling is better; the bottom of the pit is cleaned.

Dr. Cushman spoke of pinholes in templates.

Dr. Richards thought that protection depends largely on the smoothness of the work.

Mr. Hogaboom said that rough work is better as the plated deposit sticks better.

Mr. Saunders said that all steel shells for the Allies are plated.

Mr. Hogaboom, referring again to pin holes, pointed out that the different constituents in steel, such as martensite, pearlite, etc., take on the plating deposit differently.

Atmospheric Corrosion of Commercial Sheet Iron

The paper by E. A. RICHARDSON of Warren, Ohio, and L. T. RICHARDSON of Madison, Wis., on "atmospheric corrosion of commercial sheet iron" was then read by title. It is published in full on page 450 of this issue. It elicited a very lively discussion.

Dr. Cushman disagreed strongly with the conclusion of the authors. He referred to very extended tests, made by him, of a thousand full-sized sheets made up in different ways and exposed to severe tests. He concludes that pure iron stands up better than copper-steel. He referred to Sir Hadfield's work and the recent symposium in London. It all depends what the test is like. Some ancient irons contain much phosphorus and no copper. He concluded that too little attention has been paid to the effect of gases in iron or steel on corrosion.

Mr. D. M. Buck also referred to tests extending over five or six years with several thousand sheets, but he does not agree with Dr. Cushman. His experience is that the addition of copper to pure irons, as well as to any good heat of steel, is beneficial. 0.04 Cu is a distinct benefit.

Dr. Cushman said he has under test sheets with as much as 1.5 per cent Cu, but he cannot find any improvement due to copper. He emphasized that when comparing the quality of various steels we ought to have some standard test; otherwise we don't get anywhere.

Mr. Aupperle said that on the basis of several years of experiments, it is hard to tell the difference between 0.3 and 0.03 per cent Cu as to stability. Aitchison of Sheffield University found that copper-steel did not stand up as well as ordinary steel. The speaker emphasized that Messrs. Richardson had not taken into account the gas content of the samples tested. The presence of much gas in the steel may counterbalance to a large extent other effects.

Dr. Fink insisted that what we need is three or four standard tests. Otherwise we cannot compare results.

Lead from Brine Leaches

The paper by CLARENCE E. SIMS and OLIVER C. RALSTON on the electrolytic recovery from brine leaches was next presented. It was published in full in our issue of Oct. 1, page 410.

Electrolytic Zinc Dust

The paper by H. J. MORGAN and O. C. RALSTON on electrolytic zinc dust which was the next paper on the program, is published in full on page 465 of this issue.

Electrolysis of Vanadium Salt Solutions

The electrolysis of aqueous solutions of vanadium salts was the subject of an extensive paper of Dr. S. FISCHER, JR.

The paper gives the results of investigations made to determine whether or not it were possible to obtain metallic vanadium from aqueous solutions of its salts, there being but few electrolytic processes for obtaining vanadium, and the literature on the subject being very scant.

A large number of experiments were made—in all 368—and it was found that metallic vanadium could not be obtained. The electrolyte of Cowper-Coles with which he claimed to have obtained the metal was investigated, but no metallic vanadium was obtained after making 55 experiments.

A series of 112 experiments were performed on electrolytes containing another salt besides the vanadium compound. In a majority of the tests made, a black film was formed on the cathode wherever platinum was used. This film showed no indication of the presence of vanadium.

After investigating a number of inorganic and organic acids as solvents for vanadic acid, it was found that none acted satisfactorily as electrolyte.

A large number of experiments on alkali vanadate electrolytes and the anode reaction were also made, giving deposits of vanadic oxide.

A series of 33 experiments was run on sodium metavanadate, which indicated that an oxidation took place at the anode, the anode product being orange red to brick red in color. Platinum hydride was formed on a platinum cathode. In the other experiments various other alkaline electrolytes were studied.

In discussing the results the author states that it is probable that the high heats of formation of vanadium salts and the great tendency to form vanadates prevent the reduction of the compounds to metallic vanadium. Chemically it is known that vanadium oxide is extremely hard to reduce, even in the electric furnace and by the Goldschmidt thermit process.

There is very little available information as to the heat of formation of vanadium salts, and thus the deductions to explain the non-deposition of vanadium from aqueous solutions are only theoretical.

Messrs. Mott, Fink, Frary, and Blum participated in the discussion and a very interesting contribution to the discussion was an account of experiments by W. E. Koerner on the electrolytic behavior of tungsten, which is reserved for a future issue.

Electrodeposition of Nickel

The electrodeposition of nickel was the subject of a paper of L. D. HAMMOND of the University of Wisconsin.

Nickel plating, although practised for fifty years, is still based on "cut and try" methods. This paper gives the results of experiments made on the corrosion of electrolytic nickel anodes, annealed nickel anodes, and cast nickel anodes in various electrolytes. The conditions necessary for the direct deposition of nickel on zinc were investigated and the effect of boric acid addition to the electrolyte was studied.

The results are summarized as follows:

A study of the corrosion of cast nickel, electrolytic nickel, and annealed electrolytic nickel anodes was made in the following electrolytes: nickel sulphate solution; nickel sulphate solution to which boric acid was added; nickel sulphate boric solution to which various amounts of nickel chloride were added. Measurements of the total polarization pressures and current efficiency tests of these three anodes in the electrolytes listed above were made.

A study was made of the conditions necessary for the direct electro-deposition of nickel on zinc, together with some of the electrolytes which have been proposed for this purpose. Nickel can be deposited directly on zinc from baths used to deposit nickel on more electro-negative metals by employing a higher initial current density than is used with the more electronegative metals. Nickel was deposited directly on zinc from an approximately half normal hydrochloric acid solution to which 120 gm. per liter of nickel sulphate were added. The beneficial action of sodium citrate in the baths for the direct nickeling of zinc was found to consist not in changing the potential of zinc but in decreasing the rate

of deposition by immersion. Sodium potassium tartrate and sodium malate have a similar action but they do not permit the use of as high a current density as the citrate bath. The use of pure nickel anodes and the use of nickel chloride to secure anode corrosion, instead of any other chloride, is advocated. The use of nickel sulphate in the electrolyte instead of nickel ammonium sulphate is advocated.

The function of boric acid in the electrolyte is not different from that of any other acid; it simply maintains a small concentration of acid which is necessary to secure a good deposit.

In the discussion which followed Mr. Hogaboom complained that the paper was not written intelligibly to the plater. He said that small percentages of copper in nickel cause black nickel. Dr. Fink urged the platers and the trade journals for platers to adopt the metric system. Dr. Leonard Waldo eulogized the life work of the late Starr Sperry.

Nickel Plating with Rotating Cathodes

A paper on "current efficiencies in nickel plating baths with rotating cathodes," by Professor Frank C. Mathers and E. G. Sturdevant, of Indiana University, gave the results of experiments in nickel plating baths and showed that the impurities in the nickel salts are the cause of the low initial current yields with stationary cathodes and the still lower yields with rotating cathodes. The following points are brought out:

Free mineral acid can produce this lowering of the yields, but the neutralization of the baths by boiling with nickel hydroxide did not overcome the trouble.

The yields from baths electrolyzed continuously with rotating cathodes started low but reached values of about 97.6 per cent in 2, 4 and 5 hours respectively for baths of 100, 200 and 300 cc. made from commercial nickel salts. Similar baths made from purified salts gave yields of about 98 per cent for the first hour regardless of the volume. This shows that impurities produce all the lowering of the yields.

The yields with stationary and with rotating cathodes are approximately equal in all cases where the baths are sufficiently pure. Nitrate lowered the yields more than any other impurity that was tried. Ferric salts, ammonium citrate or ammonium acetate lowered the yields, but ferrous sulphate up to 2 per cent was almost without effect.

Free boric acid lowers the yields somewhat when present in quantities greater than 2 per cent.

In the discussion which followed Mr. Hogaboom said that nickel plating cannot be carried on like copper plating for refining purposes only.

Electrotyping

The last paper of this session was entitled "Preliminary Studies on the Deposition of Copper in Electrotyping Baths," the authors being W. Blum, H. D. Holler and H. S. Rawson of the Bureau of Standards. The work is not yet entirely finished and a more complete account will be published later as a technologic paper of the Bureau. The investigation was carried out at the suggestion of the Government Printing Office and was conducted in co-operation with the International Association of Electrotypers.

The paper describes investigations of the tensile strength, ductility and microstructure of copper deposited from copper sulphate-sulphuric acid solutions, upon graphited wax molds, under various conditions of deposition. The convenient conditions for satisfactory operation of copper electrotyping baths as determined by the experiments are given as follows:

1. Conditions for Deposition

Although no extended service tests of electrotypes containing copper of known properties have been made, examination of satisfactory electrotypes, and conferences with practical electrotypers has resulted in the following tentative specification for copper for electrotypes, viz., a tensile strength of 2500 to 2800 kg./cm.^{2} (35,000 to 40,000 lb./sq. in.), and an elongation of 20 to 30 per cent. For the production of such copper, the following conditions are recommended as being the most convenient for commercial practice.

A. Composition of solution. The solution should contain from 50 to 80 g./L. (7 to 11 oz./gal.) of sulphuric acid, and from 250 to 200 g./L (34 to 27 oz./gal.) of copper sulphate. In other words, the total content of copper sulphate plus sulphuric acid should be about 300 g./L. This corresponds to a specific gravity of 1.18 (22 deg. Baumé).

B. The solution should be maintained between 25 deg. and 30 deg. C. (77 deg. and 86 deg. Fahr.), unless high current densities are used. If the current density is above 8 amp./dm.^{2} (75 amp./sq. ft.), the temperature may be allowed to rise to 35 deg. C. (95 deg. Fahr.).

C. Current density. At low temperature current densities from 5 to 9 amp./dm.^{2} (47 to 84 amp./sq. ft.) may be employed. At 35 deg. C. (95 deg. Fahr.) current densities from 8 to 10 amp./dm.^{2} (75 to 93 amp./sq. ft.) are most satisfactory.

D. Agitation. The highest practicable degree of agitation should be employed, especially between the anodes and cathodes.

2. Annealing Effects

It is probable that during the process of "backing up" the shells with molten type metal, the copper of the shells is heated to such a temperature that some annealing takes place. The extent to which this occurs, or its effect upon the wearing properties of the plates, is difficult to determine. Examination of a number of finished electrotype plates, some prepared from copper deposited under known conditions, indicates that any such annealing effect has not been sufficient to make any visible change in the microstructure, though it may have produced some change in the tensile properties.

Dr. Blum, in reading the paper, showed many interesting examples of electrotyping. The appearance of the plate is not as important as tensile strength. The most important effect is that of temperature on the tensile strength of the copper.

In the discussion which followed, Dr. Waldo considered the paper to be an important contribution to our knowledge of the subject. He urged that the amount of metal deposited per kilowatt-hour as function of the current density be included in all progress on electrotyping and plating. Messrs. Hogaboom, Frary, and Tyler also participated in the discussion.

Friday Session

The concluding session of the meeting was held on Friday morning, Sept. 29, also at the Hotel Astor.

Dry Cells

A paper on "Characteristics of Small Dry Cells," by C. F. Burgess, of the Burgess Laboratories, Madison, Wis., was presented by Mr. W. B. Schulte.

The paper brought out the interesting fact that the demand for small dry cells is rapidly increasing, due to the increasing use of pocket flash-lights. The output of cells for these lights is several times the output of standard No. 6 dry cells. The development of high-efficiency, miniature tungsten lamps has aided greatly in the development of the flash-lights.

A large number of tests of small cells have been made by the Burgess Laboratories as an adjunct to manufacture. The standard method of capacity test consists in connecting an individual cell to a resistance coil of 4 ohms, and discharging continuously until the voltage drops to 0.5 volt. Another test called the "shelf-life test" (because it shows the ability of the battery to stand idle) is made by measuring the short-circuit flash which the cell gives when connected momentarily to an ammeter. This method was found to give the best means of determining deterioration within the cell. From a large number of laboratory tests on cells of different makes the desirable qualities given in Table I, have been determined.

TABLE I

Performance That Should be Expected from Good Quality of Cell

Cell Dimension	Capacity Minutes	Per Cent Monthly Deterioration
2.25 x 1.25 in. (57.2 x 38.8 mm.)......	960	Under 4%
1.8125 x 0.9375 in. (46.1 x 23.8 mm.)..	300	Under 6%
2.125 x 0.75 in. (54 x 19.1 mm.)......	250	Under 8%
1.875 x 0.625 in. (47.7 x 15.9 mm.)....	120	Under 10%
1.5625 x 0.5625 in. (39.7 x 14.3 mm.)..	65	Under 12%
1.875 x 0.5625 in. (47.7 x 14.3 mm.)...	70	Under 12%

At the conclusion of the paper Mr. Schulte emphasized the unfortunate loose form of advertising dry cells. Mr. Baldwin thought it was important to determine an exact end point of the test. Mr. Gillingham said it was hard to decide on the best test for dry cells; no rapid method is entirely satisfactory. Dr. Hering suggested the constant-wattage test as giving a very sharp end point. Mr. Schulte replied that the constant-wattage test alone is not satisfactory for testing cells for flash-light service. The cooling effect of the lamp leads increases rapidly with a slight drop in voltage.

Alkaline Storage Battery

A paper by L. C. TURNOCK of the Carnegie Institute of Technology of Pittsburgh discussed the effect of temperature upon the performance of the Edison storage battery. The storage battery finds service in climates where there are great differences in temperature between summer and winter and the effect of temperature changes on the battery is therefore important.

While the tests were carried out at twice the value of the recommended "normal" rate of charge and discharge, this fact is not thought to impair the general applicability of the results.

The results are summarized as follows:

The available current efficiency of the battery at charge and discharge rates twice the value of the recommended "normal" rates increases up to 50 deg. C. (122 deg. Fahr.), after which it begins to fall off rapidly with further increase in temperature.

The current efficiency on discharge is higher than on charge as evidenced by practically no gas evolution during discharge even at rates higher than "normal."

A more effective input into the battery is possible by keeping the temperature below 50 deg. C. (122 deg. Fahr.). The best electrical efficiency is obtained by charging at a low temperature and discharging at a higher temperature.

The operation of the battery at temperatures above 50 deg. C. (122 deg. Fahr.) is detrimental to the life of the battery. The capacity of the positive or nickel hydrate electrode may be restored by an overcharge at a low temperature. The capacity of the iron or negative electrode will continue to lose in capacity with operation at high temperatures and its lost capacity can not be restored with overcharging.

The presence of hydrogen peroxide in the electrolyte during the various states of charge of the battery may account for the low capacities experienced with the battery allowed to operate at high temperatures. On charge it functions as a reducing agent toward the positive electrode and has the effect of an oxidizing agent toward the negative electrode.

Another view explaining the low capacity of the positive and negative electrodes, and which the evidence so far obtained seems to support the more strongly, is as follows:

On charge the nickel peroxide (NiO_2) and nickelic oxide (Ni_2O_3) form a solid solution, in which the concentration of NiO_2 in the equilibrium phase decreases with increase in temperature.

The highly active metallic iron of the charged negative plates is soluble in the electrolyte and the rate of solution increases with increase in temperature. Solution of the iron in the electrolyte results in a permanent loss of capacity.

It is dangerous to allow the battery to become overheated and stand even on open-circuit in a place that is not sufficiently ventilated, artificially or otherwise. Evolution of hydrogen and oxygen, in the proper proportion to form in themselves a highly explosive mixture, is evident at 50 deg. C. (122 deg. Fahr.) and the rate increases rapidly with increase of temperature.

Dr. Frary suggested the extension of the tests to low temperatures, as this is important for automobile service in winter.

High-Temperature Heat Developed During Electrolysis

The paper by Dr. CARL HERING on this subject is published in full on page 454 of this issue. In the discussion which followed Dr. Northrup complimented the author on his paper and suggested the use of solutions containing metals. Dr. Fink suggested the use of organic liquids in the welding experiments. Dr. Frary said the phenomenon described was known not only in aqueous solutions, but also in fused salts. Mr. Mott referred to Sir Humphrey Davy's work and said he had himself tried flame arcs in liquids.

Super-Refractory Materials for Incandescent Lighting

The "Possibilities of Developing Super-Refractory Materials for Incandescent Lighting," were discussed in a paper by Dr. F. A. FAHRENWALD of the Case School of Applied Science, Cleveland, Ohio. The author states that in the list of known elements there is not one that alone will prove a serious competitor of tungsten for lamp manufacturing purposes. In view of this, it is evident that any search for the desired material must deal with combinations of elements.

He states that there is no reason to believe that proper alloy research will not develop a material for refractory, electrical-resistance lighting elements which will be more efficient than pure tungsten.

He gives the following outline as covering the field of development:

1. A super-refractory inter-metallic compound.
2. A solid solution alloy of a refractory metal, possessing lower vapor pressure than tungsten.
3. A refractory alloy having more favorable radiation characteristics than has pure tungsten.

In the discussion which followed, Mr. Mott said he had tested a great many materials in the flame arc. The determination of the melting point of vanadium is difficult. The presence of either carbon or oxygen increases the melting point. ThO_2 has the highest boiling point of any known substance. Messrs. Lloyd, Fink, and Hering also participated in the discussion.

Radium Emanation

A paper by HERMAN SCHLUNDT, T. H. LEAMING and JULIUS UNDERWOOD, of the University of Missouri, gives a "comparison of the ionization currents due to equal

quantities of radium emanation in different types of electroscopes."

Three different types of electroscopes widely used for determining radium emanations were standardized with known quantities of radium emanation. The electrical constants of the instruments were determined and also the volumes and internal surface areas of the ionization chambers. From the combined data the ionization currents per curie of emanation at the time of maximum activity were computed both from direct measurements and by applying the formula originated by Duane and Laborde.

The three instruments used were the new electroscope designed by Dr. S. C. Lind of the U. S. Bureau of Mines, the Wolf quartz-fiber electroscope, and the Mache-Meyer fontactometer. The results are tabulated in the paper.

The experimental results show that the reduction factor in the formula of Duane and Laborde has specific values for ionization chambers of the dimensions used in the experiments. In order then to convert curies into e.s. units or Mache units a reduction factor must be determined for each of these instruments, and the same is true if one desires to translate activities expressed in electrostatic or Mache units into curies or gram-seconds of radium. The authors state that the custom of expressing activities of water and gas samples in terms of Mache units should be superseded entirely by stating directly the radium content or curies per liter.

Silver-Peroxynitrate

A paper by MORTIMER J. BROWN described "a new method for the study of silver-peroxynitrate." The investigation had been carried out at Cornell University.

When silver nitrate solution is electrolyzed between insoluble electrodes, silver is deposited at the cathode and silver peroxynitrate at the anode, there being presumably a simultaneous formation of nitric acid at the anode.

Both solid deposits are crystalline, and they grow rapidly one toward the other in arborescent crystals. Because of this fact, there is no doubt that the anode product is a good electrical conductor. However, almost as soon as the electrolysis begins, the black crystals break away from the anode, are attacked by the nitric acid in solution and eventually go entirely into solution with liberation of gas.

After studying this electrolysis carefully and at considerable length in a variety of types of apparatus, transparent and opaque, the author became strongly of the opinion that so long as the peroxynitrate remained in electrical contact with the anode it was not attacked by the nitric acid simultaneously formed. It therefore seemed possible to develop a type of apparatus which would permit of the quantitative electrolytic precipitation of the peroxynitrate and the checking of its weight against the gain in copper coulometers in the same electric circuit. Previous investigators had used no apparatus specially adapted to the problem in hand, and it is highly probable that none of them had for purposes of analysis more than a part of the material originally deposited, much of it having been lost by being dissolved in the electrolyte. This one supposition held the possible explanation for discrepancies between the analyses and conclusions of different men. Special apparatus was therefore developed.

The general results of the experiments are as follows:

Solutions containing 5 per cent and 20 per cent silver nitrate were electrolyzed with various current strengths. The silver content of the anode deposits averaged 79.37 per cent Ag, the limits being 79.03 and 78.2. The ratio of the anode deposit to copper precipitated in the coulometer varied from 2.98 to 2.69. No pure oxide and no hydrated oxide can give both the observed silver content and the observed coulometer ratio. The calculated values for $(Ag_3O_4)_2.AgNO_3$ are 79.9 per cent and 2.97, while the values found for electrolysis of 20 per cent $AgNO_3$ and a current of 0.20-0.25 amp. are 79.3 per cent and 2.96; with 5 per cent $AgNO_3$ the corresponding values are 79.4 per cent and 2.75. The anode deposit is therefore impure $(Ag_3O_4)_2.AgNO_3$. The low value for the silver content may be due in part to occluded mother liquor or adsorbed silver nitrate; but this would raise the coulometer ratio and therefore cannot be the sole factor. The low coulometer ratio may be due to the presence of some substance like $(Ag_3O_4)_2.H_2O$ or $Ag_2O_3.AgNO_3$. There is nothing in the experiments to show what the admixture is or in what form it is present. The low coulometer ratio may also be due to the anode deposit being dissolved by the solution. Special experiments are needed to determine this point.

It requires ten faradays to precipitate one gram molecular weight of $(Ag_3O_4)_2.AgNO_3$. These experiments confirm the conclusions of Mulder, Tanatar, Sulc, and Watson; they are in agreement with the experimental data of Baborovsky and Kuzma, though not with their conclusions. There is no real contradiction with the data of Luther and Pokorny, because these latter are admittedly not accurate enough to warrant any conclusion beyond the one that the peroxynitrate contains a higher oxide than Ag_2O_2. Experiments should be made to determine under what conditions silver nitrate splits off from the peroxynitrate.

Equilibrium between Bromine and Potassium Bromide Solutions

The equilibrium between bromine and potassium bromide solutions at zero degree C. was discussed in a paper by GRINNELL JONES and M. L. HARTMANN, of Harvard University.

The authors of this paper have recently published a study of the influence of temperature on the free energy of formation of silver iodide, a study which revealed suggestive relationships between the thermodynamic properties of this substance, and which furnished a plausible explanation of the negative coefficient of expansion of silver iodide. Since it seemed desirable to test the generality of these relationships by a study of other similar cases, a study of silver bromide was planned. But in order to interpret measurements of the potential of the silver-silver bromide-bromine cell similar to the silver-silver iodide-iodine cells previously investigated, it is first necessary to ascertain the concentration of each of the ions present (Br^-, Br_3^-, Br_5^-, H^+, K^+), and to ascertain also the mobility of each ion. And moreover, since the temperature coefficient of the free energy is concerned these data at two or more temperatures are needed, preferably 25 deg. and 0 deg. C. This paper records and interprets the results of experimental investigations of this preliminary problem at 0 deg.

Computations based upon the results show that the following reactions occur, and that a quantitative interpretation may be secured without the necessity of assuming that any other reactions occur:

1. Bromine dissolves as Br_2.
2. $Br_2 + H_2O \leftrightarrows H^+ + Br^- + HBrO$.
3. $KBr + Br_2 \leftrightarrows KBr_3$.
4. $KBr + 2Br_2 \leftrightarrows KBr_5$.

A saturated solution of bromine in water at 0 deg. has the composition: Br_2 0.2539 moles per liter; H^+, 0.001085; Br, 0.000126; Br_3, 0.000628; Br_5, 0.000331.

The hydrolysis constant,

$$K_H = \frac{(H)\ (Br)\ HBrO}{Br_2} = 5.7 \times 10^{-10}.$$

The equilibrium constant, $K_3 = \frac{Br^- \times Br_2}{Br^-_3} = 0.051.$

The equilibrium constant $K_5 = \frac{Br^- + Br^\prime_2}{Br^-_5} = 0.0246.$

The distribution coefficient of Br_2 between water and carbon tetrachloride (after correcting for hydrolysis) is, D = 21.018 + 2.831 C, where C is concentration of Br_2 in the carbon tetrachloride.

By the aid of these constants the concentration of each ion may be computed in any solution containing known amounts of potassium bromide up to 0.1n, and known amounts of bromine up to saturation.

The conductivity of a series of potassium bromide solutions from 0.001n to 0.1n has been determined at 0 deg. C. These results when extrapolated to infinite dilution by the method of A. A. Noyes give 83.8 for the mobility of potassium bromide, and if the value for the mobility of the potassium ion is 40.1, the mobility of the bromide ion is 43.7. From the data for the specific conductivity of solutions containing bromine we conclude that the mobility of the tribromide ion is 23.5, and of the penta-bromide ion, 16.3.

Industrial Conferences on Alcohol and Motor Fuels

Two interesting conferences, one on "Alcohol, Acetone, and Acetic Acid," and one on "Oils and Motor Fuels," were held under the auspices of the American Chemical Society during its recent New York meeting at the Chemists' Club on Thursday and Saturday afternoons, respectively. An account of these conferences follows:

ALCOHOL, ACETONE AND ACETIC ACID

At the conference held Thursday afternoon at the Chemists' Club, the subjects of industrial alcohol, acetone and acetic were discussed. Dr. ARTHUR D. LITTLE presided. It was predicted that cheap alocohol would find its largest use as a motor fuel. Sawdust was mentioned as a source which offers great possibilities. Black strap molasses, wood waste and waste sulphite liquor and other products were also discussed.

Dr. Little said that the potato distilleries are located in Europe, mostly in Germany. The grain distilleries are mostly in this country, in the Middle Western States, and the molasses distilleries along the southern and eastern coast. Alcohol from wood waste is produced only at Georgetown, S. C., and Fullerton, La., and from waste sulphite liquor at Mechanicsville, N. Y. He read a letter from J. Stuart Groves, who has been in charge of the plant of the du Pont Powder Company, making alcohol from yellow pine wood waste. According to this letter the process has been found very successful at this plant. Dr. Little thought the acetone production must be 10,000 tons per year at present, having been greatly stimulated by the war. Several processes were discussed, among which was an interesting development at the Shawinigan Falls Power Company, in Canada, where synthetic acetone is produced from calcium carbide by way of acetylene.

Dr. Matthewson, of the Shawinigan Falls Power Company, discussed the acetone process mentioned by Dr. Little. He said that a large plant is nearly finished and operations would be started on the manufacture of formalin, acetone and acetic acid in about three weeks. In the experimental work the chief difficulties were mechanical, especially in finding a material to stand sulphuric acid, and in the oxidation of formaldehyde with acetic acid. Oxygen was tried and found to be fairly successful, the danger of explosion being eliminated by proper regulation. By the first of the year it is expected that 10 to 15 tons of acetone per day will be turned out. Dr. Matthewson thought it doubtful whether the acetone process would pay under normal conditions, as there was an overproduction of acetone, but the other products could probably be made cheap enough to compete.

Dr. Little said there was a use for acetic anhydride which promises to become important, and that is in connection with the production of cellulose acetate which is finding increasing use in explosives, varnishes, auto goggles, artificial silk, and motion picture films.

In reply to a question from Dr. Gibney, of the U. S. Ordnance Department, as to the quality of wood waste alcohol, Dr. Little said it was perfectly feasible to produce a 95 per cent alcohol of the grade of cologne spirits, from wood waste.

Dr. Kyrides said that synthetic rubber becomes a greater possibility with cheap alcohol and acetone. Mr. Breckler said he had been associated with the alcohol business for twelve years, and that he thought the molasses alcohol companies held the situation in their hands. He said the only hope for alcohol was from sulphite liquors, the unfortunate part being that it requires special skill and training. In reply to a question he said that with molasses at 4½ cents alcohol could probably be produced at 20 cents per wine gallon.

Dr. Little said there were two plants running under the Ewing and Tomlinson process, and that the one at Fullerton, La., was producing 2000 to 2500 gallons per day. He said the day of 25-cent alcohol was coming, and that it would be preferred to gasoline as a motor fuel.

A conference was held at the Chemists' Club Friday afternoon on "Medicinal Chemicals," at which Dr. HAROLD HIBBERT presided.

OILS AND MOTOR FUELS

On Saturday afternoon a conference was held on the above subject, at which Dr. RAYMOND F. BACON, of the Mellon Institute, presided. At this conference a closer co-operation between automobile manufacturers and the makers of petroleum products was thought to be the only solution of the gasoline shortage problem. It was agreed that products do not always run uniform, that methods of testing do not always show the availability for a certain purpose, and that standardization was necessary.

Dr. Bacon said there was a great need for flexibility in refining so that the product in greatest demand can be readily produced. He also advocated a closer co-operation between the auto manufacturers and the refiners of petroleum. He said kerosene is being used more and more in trucks, and the further development of this field offers great possibilities.

Dr. Walter F. Rittman said that the chemist must co-operate with the automobile engineer so that the most efficient motor may be developed. He warned against the use of "gasoline savers," as they are usually 90 per cent kerosene, and often contain explosives.

Dr. Maberry said there should be a line of individual investigation of motor oils and fuels carried out on a larger scale, and Dr. Conrad agreed that it was a great field for the universities and schools, also the Bureau of Standards.

Others who took part in the discussion were Messrs. Day, Salisbury, Kelley, Baker, Parish, Gray, Robbins, and Humphreys.

One Hundred and Thirteenth Meeting of the American Institute of Mining Engineers

Arizona, September, 1916

It is undoubtedly the first time in the history of the Institute that a meeting was conducted on the basis of the one in Arizona. The novelty consisted in traveling at night, thus covering long distances, and conducting the meeting proper at different points along the road. There is not a member of those that partook of the Arizonian hospitality who does not feel as if he were now thoroughly acquainted with the land of wonders and with its kind and jovial citizens.

Arizona has, within the last six years, undergone a development in the metallurgy of copper which is marvelous. While Arizona always was a copper-producing state and such properties as the Copper Queen and the Old Dominion have produced copper over an extended period of years, the improvements made in processes and in plant construction can be best shown by citing the development of, say, the Warren District, near Bisbee. From 1880 to 1885 this district produced 34,356,000 lb. of copper. The annual production of copper in 1890 was 9,000,000 lb., in 1900 it was 34,000,000 lb. and in 1910 it was approximately 135,000,000 lb. copper. The production for the year 1915 was 165,000,000 lb. copper, 10,000,000 lb. lead, 55,000 oz. of gold and 2,350,000 oz. of silver. Similar developments may be observed in the other districts. It was, therefore, with an extraordinary amount of interest that the disciples of the mining and metallurgical industries, not alone of the United States, but also from Canada and Mexico, congregated at El Paso and turned their wondering eyes towards Arizona.

The interest taken in this meeting is best shown by giving a list of the members who participated on this trip.

L. M. Allen, Globe, Ariz.; J. J. Ambrose, Hayden, Ariz.; F. T. Anderson, El Paso, Tex.; C. E. Arnold, Miami, Ariz.; J. Owen Ambler, Douglas, Ariz.; George D. Barron, Rye, N. Y.; Mrs. George D. Barron, Rye, N. Y.; Percy E. Barbour, New York, N. Y.; A. D. Beers, New York, N. Y.; P. G. Beckett, Globe, Ariz.; I. H. Barkdoll, Globe, Ariz.; L. A. Blackner, Ray, Ariz.; A. L. Blomfield, Denver, Col.; F. C. Blickensderfer, Bisbee, Ariz.; W. B. Boggs, New York, N. Y.; Mrs. M. Bookman, St. Louis, Mo.; R. R. Boyd, Globe, Ariz.; S. D. Bridge, Comfort, Tex.; C. J. Briggs, El Paso, Tex.; W. L. Bradt, Saginaw, Mich.; J. F. Brown, Goldfield, Nev.; W. C. Browning, Superior, Ariz.; D. W. Brunton, Denver, Col.; H. P. Bowen, Miami, Ariz.; H. A. Buehler, St. Louis, Mo.; Edward E. Bugee, Boston, Mass.; G. N. Bjore, Globe, Ariz.; W. Burns, Morenci, Ariz.; G. M. Colvocoresses, Humboldt, Ariz.; K. P. Campbell, Sasco, Ariz.; Will L. Clark, Jerome, Ariz.; Charles A. Chase, Denver, Col.; Carl H. Cole, David Cole, El Paso, Tex.; Mrs. David Cole, El Paso, Tex.; Norman Carmichael, Clifton, Ariz.; F. G. Cottrell, Washington, D. C.; Ben H. Cody, Clifton, Ariz.; H. Cooper, El Paso, Tex.; W. M. Claypool, W. B. Cramer, Globe, Ariz.; Arthur Crowfoot, Morenci, Ariz.; Joseph F. Cullen, Midvale, Utah; G. H. Clevenger, Palo Alto, Cal.; Q. F. Davis, A. B. Calhoun, Globe, Ariz.; S. H. Davis, Joplin, Mo.; Arthur C. Danian, Denver, Col.; Geo. C. Dewey, Selby, Cal.; Albert Doerr, South Pasadena, Cal.; R. G. Dufourcq, El Paso, Tex.; Kuno Doerr, El Paso, Tex.; S. G. Dolman, Ray, Ariz.; H. F. Durker, El Paso, Tex.; A. V. Dye, Douglass, Ariz.; E. G. Deane, Miami, Ariz.; H. I. Duncan, Globe, Ariz.; R. H. Dickson, Warren, Ariz.; W. M. Drury, El Paso, Tex.; Howard Eckfeldt, South Bethlehem, Pa.; Karl Eilers, New York, N. Y.; J. A. Ede, La Salle, Ill.; J. N. Ede, J. D. Ede; Fred. B. Ely, Superior, Ariz.; M. Elsaser, Los Angeles, Cal.; C. T. Emerich, Globe, Ariz.; M. J. Elsing, Mrs. M. J. Elsing, E. N. Englehardt, I. A. Ettinger, Superior, Ariz.; Robert Faulkner, Lebanon, Pa.; Percy LeR. Fearn, New York, N. Y.; Leon Feuchere, Warren, Ariz.; J. G. Flynn, Miami, Ariz.; Robert Franke, Miami, Ariz.; Siegfried Fischer, Jr., Golden, Col.; F. N. Flynn, Clifton, Ariz.; Paul R. Forbes, W. I. Garms, Hayden, Ariz.; Walter Garms, Ray, Ariz.; Wm. D. Gordon, El Paso, Tex.; J. C. Greenway, Warren Ariz.; B. Britton Gottsberger, Miami, Ariz.; C. A. Grabill, El Paso, Tex.; W. F. Geiger, Miami, Ariz.; R. J. Glendinning, Salt Lake City, Utah; Alden D. Groff, New York, N. Y.; W. B. Gohring, Warren, Ariz.; W. E. Gaby, Butte, Mont.; Walter Gross, Perth Amboy, N. J.; C. W. Goodale, Butte, Mont.; Justice Grugan, New York, N. Y.; R. Dawson Hall, New York, N. Y.; H. T. Hamilton, Macozari, Mex.; Walter Harris, Globe, Ariz.; Stewart Hazelwood, San Francisco, Cal.; Herbert E. Hambleton, El Paso, Tex.; A. M. Hamilton, Sasco, Ariz.; James W. Hamilton, El Paso, Tex.; R. S. Handy, Kellogg, Idaho; E. Harms, Torreon, Mexico; Jas. L. Head, Warren, Ariz.; E. N. Hobart, Nogales, Ariz.; F. W. Hoar, Globe, Ariz.; J. H. Hensley, Jr., Miami, Ariz.; L. O. Howard, Globe, Ariz.; James W. Hambleton, El Paso, Tex.; G. W. Hay, A. B. Hardje, Philadelphia, Pa.; Justin H. Haynes, Denver, Col.; H. O. Hammond; Roger W. Hay, Warren, Ariz.; Edward C. Hegeler, Danville, Ill.; Miss. Hegeler, Danville, Ill.; Julius W. Hegeler, Danville, Ill.; E. C. Hickman, East Helena, Mont.; F. G. Hills, Leadville, Col.; J. P. Hodgson, Bisbee, Ariz.; M. P. Hall, Clifton, Ariz.; Alexander Imhoff, Los Angeles, Cal.; T. J. Jenks, Wickenburg, Ariz.; Mrs. S. J. Jennings, Sidney J. Jennings, Miss Amy S. Jennings, Miss Mary A. Jennings, New York, N. Y.; Wm. Strickler Jones, Atlantic City, N. Y.; Frank E. Johnson, Salt Lake City, Utah; Ira B. Joralemon, Warren, Ariz.; G. W. Kays, Kingman, Ariz.; D. N. Kay, Ray, Ariz.; S. J. Kidder, Mogollon, N. M.; R. B. T. Kiliani, New York; K. L. Kithil, Tucson, Ariz.; Edward H. Koenig, Perth Amboy, N. J.; R. W. Kerns, Warren, Ariz.; A. S. Konselman, Cananea, Mex.; O. M. Kuchs, Tooele, Utah; C. R. Kuzell, Anaconda, Mont.; J. J. Kruttschnitt, Jr., Tucson, Ariz.; E. H. Laws, Salida, Col.; William Lennox, S. H. Levison, Hayden, Ariz.; John Langston, New York; C. Legrand, Douglas, Ariz.; A. G. McGregor, Bisbee, Ariz.; P. M. McHugh, Denver, Col.; F. W. Maclennan, Miami, Ariz.; Alan F. McCormack, El Paso, Tex.; R. M. McIntosh, Mrs. McIntosh, Lake Linden, Mich.; W. E. McCourt, St. Louis; Wm. T. MacDonald, Hayden, Ariz.; Ellwood V. Matlack, Jr., Webster Groves, Mo.; E. V. Matlack, Webster Groves, Mo.; E. R. Marble, Hayden, Ariz.; F. J. H. Merrill, Los Angeles, Cal.; Seeley W. Mudd, Los Angeles, Cal.; E. P. Mathewson and wife, Anaconda, Mich.; J. F. Manning, Holkol, Korea; E. M. Marshall, Globe, Ariz.; A. H. Means, Tucson, Ariz.; H. I. Merricks, Miami, Ariz.; Edwin W. Mills, Holkol, Korea; Chas. A. Mitke, Bisbee, Ariz.; McHenry Mosier, Bisbee, Ariz.; H. W. Morse, Los Angeles, Cal.; Philip U. Moore, St. Louis, Mo.; P. A. Mosman, New York; Mr. and Mrs. C. W. Merrill, San Francisco, Cal.; H. T. Murray, Hayden, Ariz.; R. T. Murrill, Flat River, Mo.; Henry W. Nichols, Chicago, Ill.; H. L. Norton, Globe, Ariz.; Arthur Notman, Warren, Ariz.; T. H. O'Brien, Dawson, N. Mex.; J. J. Ormsbee, El Paso, Tex.; J. H. Payne, Bisbee, Ariz.; Mrs. J. H. Payne, Bisbee, Ariz.; H. D. Pallister, El Paso, Tex.; E. F. Pelton, Basil Prescott, El Paso, Tex.; Wm. J. Quigly, El Paso, Tex.; O. C. Ralston, Bisbee, Ariz.; F. L. Ransom, Salt Lake City, Utah; William H. Rea, Pittsburgh, Pa.; Mrs. Wm. H. Rea, Pittsburgh, Pa.; Miss Rea, Pittsburgh, Pa.; C. E. Rhodes, Pasadena, Cal.; Miss Marion Rice, Schenectady, N. Y.; Luther V. Rice, Chicago, Ill.; Stuart L. Rawlings, San Francisco, Cal.; E. E. Reyer, El Paso, Tex.; Walter A. Richelsen, Cananea, Sonora, Mex.; Ezrab Rider, Bisbee, Ariz.; J. F. Robertson, Coniston, Ont.; G. H. Ruggles, Miami, Ariz.; E. M. Robinson, South Bethlehem, Pa.; A. E. Ring, Flat River, Mo.; E. W. Rouse, B. E. Russell, Ray, Arizona; L. D. Ricketts, Warren Ariz.; Mrs. L. D. Ricketts, Warren, Ariz.; F. Rutherford, Douglas, Ariz.; Carl Scholz, Chicago, Ill.; E. M. Sawyer, Tyrone, N. M.; Gerald Sherman, Bisbee, Ariz.; H. R. Simpson, Los Angeles, Cal.; Paul Sterling, Wilkes-Barre, Pa.; Bradley Stoughton, New York, N. Y.; F. W. Solomon, Miami, Ariz.; K. M. Simpson, Los Angeles, Cal.; C. D. Schultz, W. P. Schunacher, El Paso, Tex.; Mrs. Bradley Stoughton, New York, N. Y.; Walter A. Schmidt, Los Angeles, Cal.; Mr. Francis S. Schimerks, E. G. Snedaker, Goldfield, Nev.; S. P. Sparks, E. G. Spilsbury, New York City; P. A. Steger, Miami, Ariz.; Howard D. Smith, San Francisco, Cal.; Paul Stein, El Paso, Tex.; E. D. Stewart, El Paso, Tex.; Roger Strobel, East Helena, Mont.; Wilmer C. Swarbley, Philadelphia, Pa.; B. B. Thayer, New York; John C. Taylor, Denver, Col.; Knox Taylor, High Bridge, N. Y.; Roscoe Teats, Tacoma, Wash.; O. J. Tuschka, Globe, Ariz.; R. E. Vening, Perth Amboy, N. J.; G. D. Van Arsdale; Arthur P. Watt, San Francisco, Cal.; J. H. Watkins, Washington, D. C.; Harry S. Ware, Anaconda, Mont.; J. R. Webster, Morenci, Ariz.; J. L. White, Humboldt, Ariz.; P. D. Wilson, Warren, Ariz.; J. R. Woodul, Mex.; Phillip Wiseman and Mrs. Wiseman, Los Angeles, Cal.; H. E. Williams, Mrs. H. E. Williams, Calumet, Mich.; A. J. Weinig, Telluride, Col.; C. L. Wolfle, El Paso, Tex.; J. S. Williams, R. B. Yerxa, Miami, Ariz.; Wm. H. Yeardle, Jr.; H. M. Ziesmer, Bisbee, Ariz.

The institute members were received open-armed at El Paso. The various local committees did everything in their power to make the stay at El Paso as pleasant and lucrative as possible. The Toltec Club was at the members' disposal. Automobiles were provided for touring the city and the military camps. The El Paso smelter was visited and the evening was spent at a Mexican dinner with Mexican music.

September 18th at Santa Rita, N. M.

The opening day of the meeting proper was the 18th. On arriving at Santa Rita, N. M., the open pit mines of the **Chino Copper Company** were visited. Then a short trip was made to Hannover, N. M., to inspect the dry mill of the **Empire Zinc Company.**

The mill was designed and put in operation by L. G.

Rowand. The operation proper was started in June, 1916. The ore treated is hard dense sulphide with contact rock and lime stone-carrying sphalerite, galena and other sulphides. Practically all the minerals are more or less magnetic, with the exception of the limestone and the galena. The feed to the separating department is closely sized, giving eight sizes between 10 mesh and 150 mesh. Practically all material through 150 mesh is removed by the dust separator. Rowand-Wetherill magnetic separators are used and the various products obtained have the composition given in Table I.

TABLE I—AVERAGE MILL RESULTS ON ROWAND WETHERILL MAGNETIC SEPARATORS

	Per Cent of Feed	Approximate Assays			
		Zn.	Pb.	Fe.	Ins.
Feed	100	18	0.2	6	39
Pole 1, 2 c. o., 3 c. o.	44	5	tr.	8	51
Pole 2 and 3 (part)	9	10	0.1	5	46
Pole 3 (part) and 4, concentrate	24	40	0.1	..	..
Pole 5 and 6, concentrate	6	51	0.1	..	..
Tails	4	10	12	16	23
Dust	11	20	0.1	4	34
Loss	2	..	...	..	..

Certain of the products are stored and saved for further use. The average recovery of zinc in concentrate is 67 per cent.

On returning to Santa Rita, a barbecue was given in honor of the Institute members by the people of the town, which was enjoyed by all present. The afternoon was spent at the **Mill of the Chino Copper Company** at Hurley, N. M. The mill seems somewhat crowded, due to the fact that it was built to handle 5000 tons, while it is actually handling 9500 tons. In 1915 the mill of the Chino Copper Company produced 68,293,893 lb. of copper. The flotation process used at the mill is rather complicated, sulphides, oxides, carbonates and even metallic copper being floated.

The day was terminated by an open-air dance.

September 19th at Douglas, Arizona

On arriving at Douglas the **Reduction Works of the Copper Queen Consolidated Mining Company** were visited. The special features of this plant are: the bedding system for ores and the entire making up of the charge before entering the furnaces; large dust chambers and the arrangement of the blowers in the power house, one blower being supplied for each furnace. The equipment of the plant consists of 10 blast furnaces, 3 reverberatory furnaces, 9 converter stands of the 12-ft. vertical type and 16 McDougall 18-ft. multiple-hearth roasters. The capacity of the plant is 4500 tons of charge per day. Fig. 1 represents the flow-sheet of the works and is self-explanatory.

Fig. 2 is the flow-sheet of the **Smelter of the Calumet & Arizona Mining Company** (p. 483). The striking feature of this plant is its cleanliness, giving a general idea of the efficiency of the plant. The Messiter system of bedding is employed, three beds of 7000 tons each for the blast furnace charge, three beds of 10,000 tons each for the roaster mixture and a coke storage pile between being used.

The roaster plant consists of twelve 21½-ft. Herreshoff air-cooled furnaces with six hearths. These furnaces are arranged in two rows of six units. The gases from these roasters pass through a longitudinal flue between the two rows of furnaces to a hollow-tile dust chamber 140 ft. long and from this to a stack 279 ft. high and 20 ft. in diameter. Four oil-fired reverberatory furnaces, 19 ft. x 100 ft., occupy the space between the blast fur-

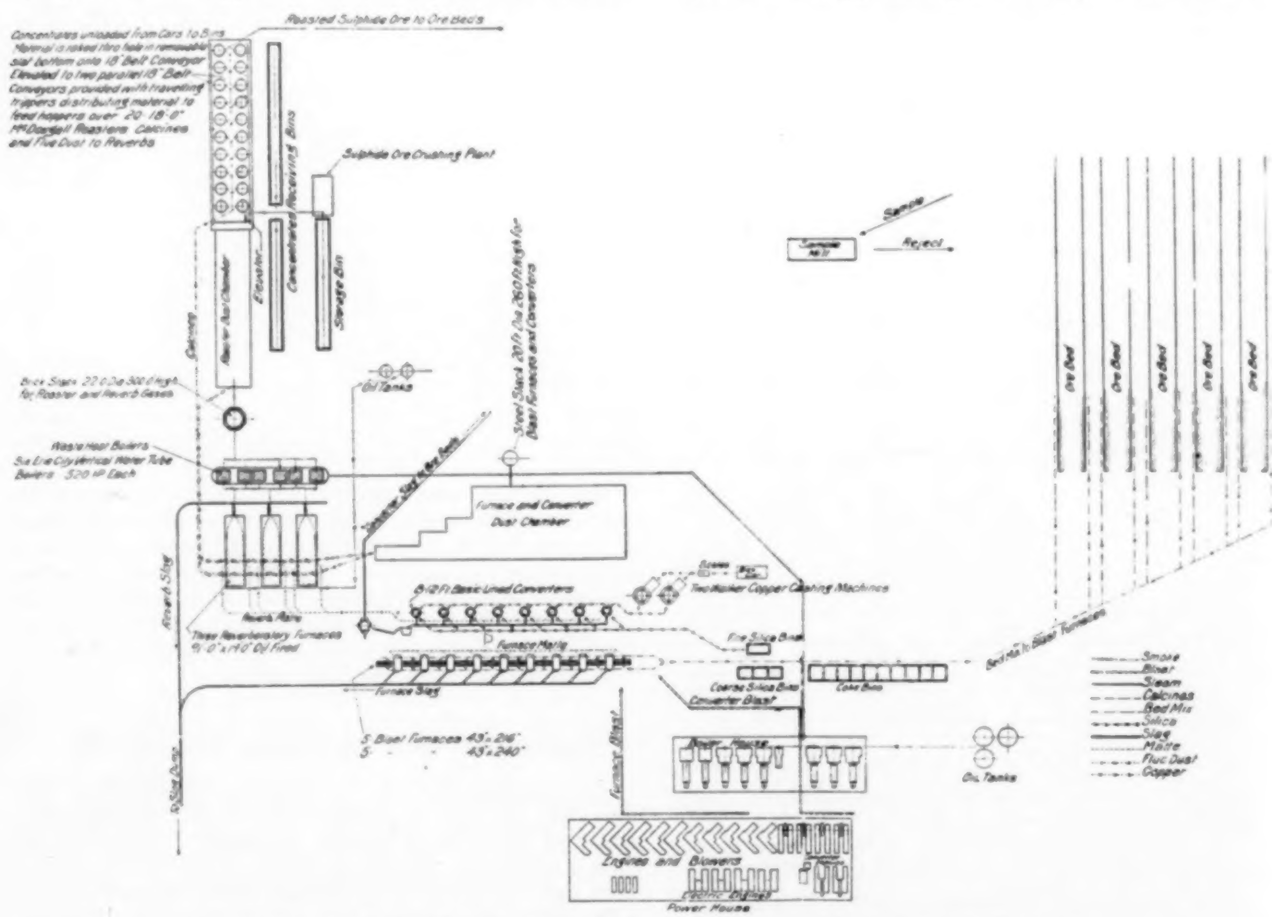


FIG. 1—FLOW SHEET OF THE COPPER QUEEN CONSOLIDATED MINING COMPANY

nace and the converter buildings. Three of these furnaces are in continual operation. The blast furnace department consists of two furnaces 40 ft. x 4 ft. at the tuyeres. The matte and slag overflow continually into settlers. The gases pass through uptakes to a chamber 180 ft. long and 2340 sq. ft. in cross-section and then to a brick-lined stack, which also takes care of the gases from the reverberatory plant. The converter building contains six stands with two extra shells of the Great Falls type basic-lined converters, 12 ft. in diameter, two 40-ton Morgan cranes, two 40-mold electrically-operated straight line casting machines and a McGregor skull breaker. The gases from the converters pass through a seperate flue to a chimney 200 ft. high and 16 ft. in diameter.

Much new construction is under way, the main new features being the increasing of the smelter capacity and a 200-ton chamber acid plant. The chamber acid produced will be used in connection with the leaching operation of the New Cornelia Copper Company at Ajo, Ariz.

Session on Smelting

The first technical session was held in the afternoon on smelting. The session was presided over by W. DOUGLAS. An address was made by President L. D. RICKETTS, followed by an address of welcome by J. C. GREENWAY. B. B. THAYER made the speech of thanks.

The first paper read was: *Features of the New Copper Smelting Plants in Arizona*, by A. G. MCGREGOR and B. S. WARREN. This paper has been printed in part in the Sept. 15 issue of this journal, pages 329 to

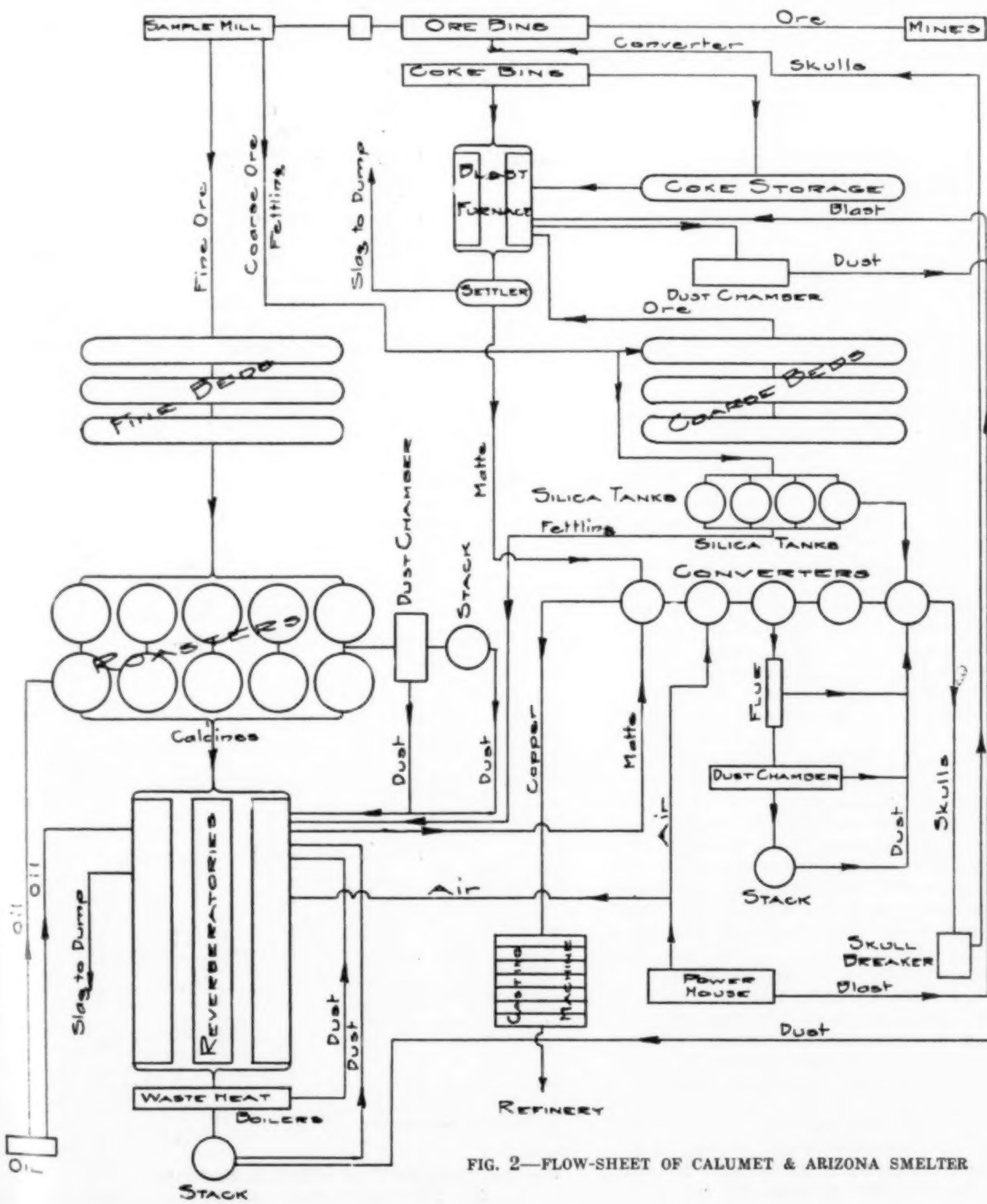


FIG. 2—FLOW-SHEET OF CALUMET & ARIZONA SMELTER

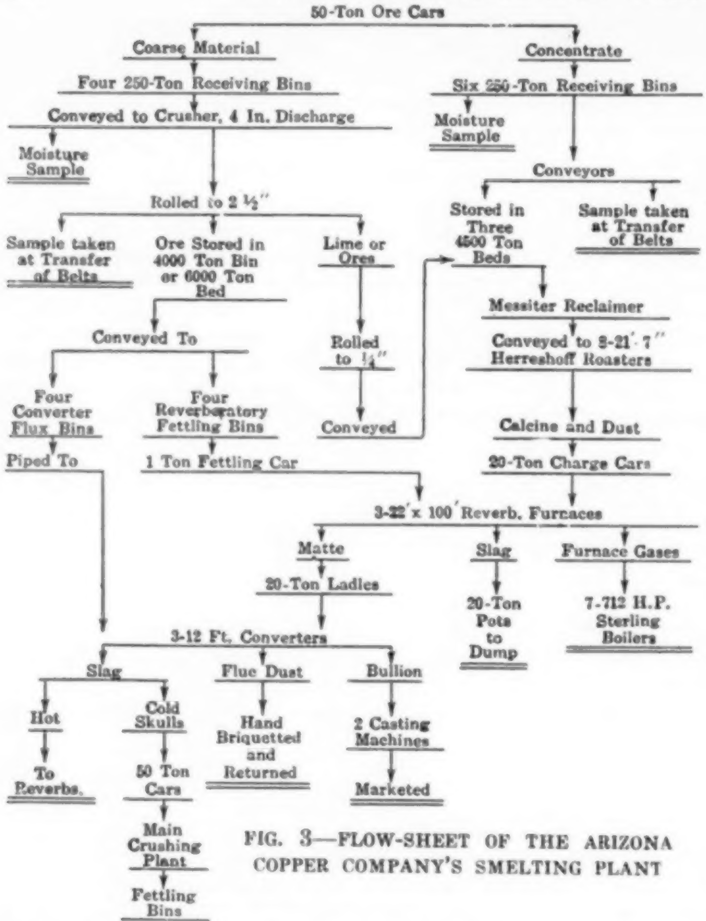


FIG. 3—FLOW-SHEET OF THE ARIZONA COPPER COMPANY'S SMELTING PLANT

337. The paper was discussed by W. DOUGLAS, L. D. RICKETTS and E. P. MATHEWSON.

The second paper read was entitled, *Smelting at the Arizona Copper Co.'s Works*, by F. N. FLYNN. The paper discusses in detail the construction and operation of the plant. Fig. 3 gives a flow-sheet of the smelter, which needs no further explanation.

The *Basic-Lined Converter in the Southwest* is the title of the paper by L. O. HOWARD, an extract of which was read by Bradley Stoughton. The paper deals essentially with the development of the use of the basic-lined converter in Arizona, giving at the same time operating-cost data. The paper was discussed by W. DOUGLAS, S. J. JENNINGS and E. P. MATHEWSON, the latter bringing out the point that it would be of great value to have comparative cost data between the vertical and the horizontal basic-lined converters.

The last paper read at this session was entitled *Determinations of Dust Losses at the Copper Queen Reduction Works*, by A. MOORE SAMUEL. It describes the methods and apparatus used for making the tests, and shows that such tests are not only essential, but economical to the general working of the plant. The fact is pointed out that dust determinations, no matter how conducted, are subject to many errors, and conclusions can only be correctly drawn from averages of a large number of tests conducted on the individual localities where dusting occurs. In this work, 10 per cent is allowed for probable errors, indicating the limited accuracy of the tests. The conclusions drawn from many experiments decided the engineers of this company to build two new flues. One of these will carry the roaster gases from the roaster dust chamber to the inlet end of the reverberatory chamber, and the other will carry the reverberatory gases from the header at the back of the boilers directly to the stack. In this manner the roaster gases will have an increased travel of 132 ft. at a low velocity, and will reduce the dust losses of the roasters considerably. The paper was discussed by W. DOUGLAS, L. D. RICKETTS, A. G. MCGREGOR, E. P. MATHEWSON, and S. J. JENNINGS.

Session on Leaching

The evening session on leaching was presided over by H. W. MORSE. The first paper read was: *Leaching Tests at New Cornelia*, by H. W. MORSE and E. A. TOBLEMAN. This paper deals essentially with the work done in the past year to determine finally the type of leaching plant to be installed.

The process decided on is briefly as follows: The ore is crushed to about 4-mesh; leached eight full days by counter current; washed with three to four counter-current wash waters; solutions practically neutral during last two days of contact with ore, is sent through reduction towers, where it meets sulphur dioxide in counter current. The ferric iron is thus reduced to below 0.4 per cent; then it goes to a revolving tumbler in which there is cement copper. There the ferric iron is still further reduced, and a corresponding amount of cement copper goes into solution. From the cement-copper tumbler the solution passes to a settling pond and then into the electrolytic cells, where a part of the copper is removed; then back into the leaching system, passing first through the oldest ore, which has already been leaching for seven days, and so on to begin the cycle again.

The flow-sheet of the 5000-ton leaching plant under construction is given in Fig. 4, and indicates clearly the individual steps of the process.

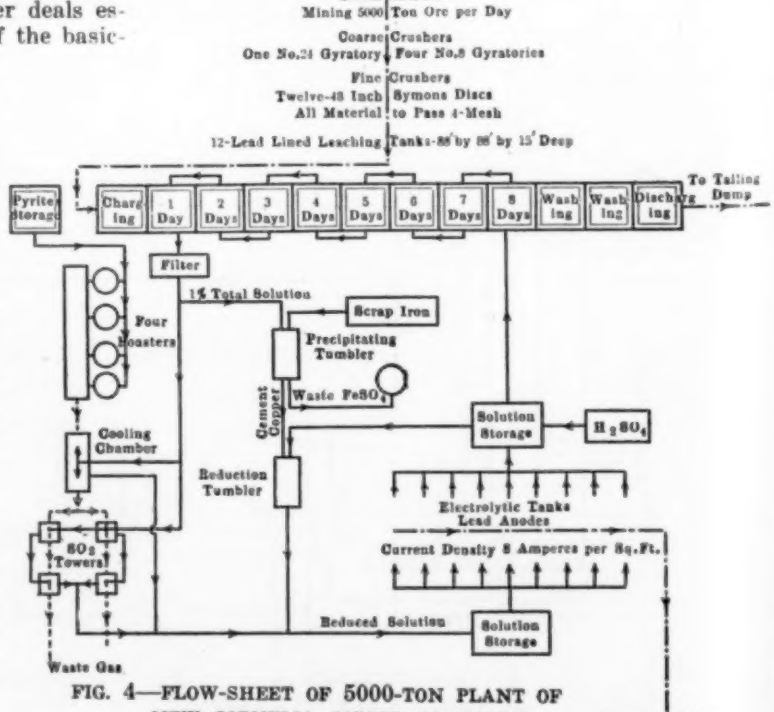


FIG. 4—FLOW-SHEET OF 5000-TON PLANT OF NEW CORNELIA COPPER COMPANY

What may be expected from the large plant is briefly summarized as follows: The extraction of a 1.4 per cent ore, using closed wash cycle, is 82 per cent, and using an extra wash, 83 per cent; the acid consumption per pound of copper, figured on 100 per cent H_2SO_4 is 3 lb.; the power efficiency in electrolysis, with lead anodes, is 1 kw.-hr. per pound of cathode copper; 0.5 lb. of sulphur is consumed per pound of cathode copper; it is only necessary for the neutral electrolyte to pass through the reducing tower; to control fouling of the electrolyte it is essential to pass about 1 per cent of the total solution volume over iron; approximately 12 per cent of the total copper will pass through the cement-copper side of the cycle, and finally the circulation of the electrolyte in the large plant will require a smaller volume than that obtained in the testing plant.

The discussion was led by LAWRENCE ADDICKS (communicated), G. D. VAN ARSDALE, S. J. JENNINGS, F. S. SCHIMERKA, and F. N. FLYNN. The main trend of the discussion was to prove that, given a fair trial, graphite anodes will bear up at least as well as lead anodes.

The second paper offered was: *2000-Ton Leaching Plant at Anaconda*, by FREDERICK LAIST and HAROLD W. ALDRICH. The paper was outlined by E. P. Mathewson. The material to be treated is accumulated tailings of the New Works dump, which amounts to about 20,000,000 tons, the copper and silver in the material amounting to approximately 0.64 per cent and 0.48 oz. per ton respectively. The dump is excavated by an electric hoist, and is loaded into 50-ton cars, which are hauled to the storage bins at the leaching plant. The storage bins hold 6000 tons and give a three days' supply.

From the bins the material goes to the 28 McDougall-type, six-hearth furnaces, each having a 20-ton feeder hopper, which are fed by belts. The furnaces are connected in four rows of seven each, and over each of the flues runs a gas flue, the four of which combine in a balloon flue with a downtake of 45 deg., which collects the dust and leads to the 200-ft. steel stack. The furnaces are air-cooled by means of blowers, the air intake being at the top of the furnace shaft and discharge being at the bottom, and leading to the leaching plant, where the hot air is used for heating purposes. Each furnace has a cooler 19 ft. long and 30 in. in diameter. The cooled concentrates enter a concrete-lined steel cylinder, which acts as a mixer, at the head end of which a very small stream of water is added to settle the dust. The moist calcines then are conveyed to the leaching house by means of an 18-in. conveyor.

The leaching plant contains ten circular redwood tanks 50 ft. in diameter and 14 ft. in height, the average charge per tank being 1000 tons of calcine. Above the ordinary slate filter bottom are two layers of heavy cocoa matting, and on top of this is a grating made of 1¾ by 3½-in. material so as to give 6-in.-square spaces. This grating fills up with calcine 3½ in. in height, preventing the tearing of the matting by the sluicing waters. The tanks are in two rows of five each, and over each row passes a 20-in. belt conveyor with trip arrangements which dump the calcines into the distributors. Each tank has three lead pipes for the acid solutions and one iron one for water. Above each tank is a storage tank of iron for the 60 deg. Be. acid stock, which is fed to the solution as it enters the leaching vat. Sluice boxes at the bottom of the vats lead to launders which connect with the tailings launder. The solution tank building is a leanto to the leaching house, and contains five tanks 50 ft. in diameter and 14 ft. deep.

The precipitation of the copper and silver on scrap iron is done in specially designed concrete launders 250 ft. long and having a section of 4 by 8 ft. available for the iron.

Details of Operation.—The tailing is subjected to an oxidizing roast at approximately 500 deg. C. The calcines, after being cooled by a special system, are conveyed to the leaching house on belt conveyors. The leaching is accomplished by continuous downward percolation. The rate of percolation varies from 3 in. to 10 in. per hour for the first solution and the final wash water respectively. The operation is conducted between 40 deg. C. and 50 deg. C. To saturate a charge it requires approximately one-fourth of the weight of calcine in weight of solution.

The five tanks are divided as follows: One for each of the No. 1 and the No. 2 solution, one for the copper solution, and two for the wash water. After a tank is charged and leveled, 250 tons of No. 1 solution, containing 0.8 per cent Cu. 5 per cent H_2SO_4, and 7 per cent NaCl is added. The solution drains through a drain at the bottom to the copper solution tank. The copper solution contains 1.9 per cent copper, 1 per cent H_2SO_4, and 7 per cent NaCl. From the copper-solution tank the copper liquor flows through precipitation launders, where the copper and the silver are removed. Two-thirds of the solution from the launders goes back to No. 2 solution tank and the rest is discarded to prevent early fouling of solution system.

After all of the No. 1 solution has been added, and allowed to drain until none of it shows on the surface of the calcines, 1 per cent of the weight of the charge of salt is spread over the calcines. This is followed by 100 tons of No. 2 solution, but with enough H_2SO_4 to bring its strength up to 20 per cent acid. This is again followed by an addition of ordinary No. 2 solution. For a depth of 4 to 5 ft. a very strong chloride solution is traveling through the charge. As there is about 8 per cent ferrous and ferric iron in the solution, this forms ferric chloride, which is a strong corrosive reagent and enables the extraction of the silver, which otherwise would be only slightly attacked. Another benefit derived from the ferric chloride in the solution is that it will attack unroasted sulphide. The two No. 2 solutions, after draining, go to the No. 1 solution tank. The last addition of the No. 2 solution is followed by 300 tons of hot water. This wash water, minus a quantity sufficient to make up for the discarded solution, goes to the two wash-water tanks, the balance being conducted to the No. 2 tank. This latter makes up the amount of solution lost in the precipitation division. The precipitation of the values on the scrap iron needs no discussion. The wash-water composition is Cu: 0.2 per cent H_2SO_4; 1 per cent and NaCl: 1 per cent.

Results.—The blister copper produced carries about 70 per cent copper. The plant, during October, 1915, gave an extraction of 80 per cent of the copper and 60 per cent of the silver. The extraction is lower than the assays of the heads indicated, but various plant losses are somewhat high, especially that of the roaster department, where the dust losses amount to 4.5 per cent of the copper in the feed.

The paper was shortly discussed by F. N. FLYNN.

Possibilities in the Wet Treatment of Copper Concentrates, by LAWRENCE ADDICKS, was the last paper offered at this session. The article deals with experimental work conducted on Nacozari and Tyrone concentrates in an endeavor to find a commercial wet method for handling and treating concentrates in general. The topics covered experimentally are screen analysis, roasting, leaching, chloridizing the residues, and the recovery of the copper from solutions.

Large scale tests on roasting indicate the possibility

of obtaining high copper and low iron solubility. The residue after leaching, however, will contain sufficient copper to make further treatment necessary. Gold and silver also remain in the residues. The tyrone concentrates alone were subjected to large acid leaching tests. The acid consumption was found to be 2.28 lb. of 100 per cent H_2SO_4 per pound of copper. The leaching was conducted at 125 deg. F., with 5.6 per cent free acid in the liquor entering the trough. Generally, when a 15 per cent copper calcine is fed to the trough, the residue at the end of the trough will run 8 per cent copper, the extraction representing the instantaneously soluble copper. The residue may be brought down to 3.5 per cent copper by suitable agitation, with a consumption of a little over 2 lb. of acid per pound of copper, and with the extraction of a little iron. The final residue weighs only about 60 per cent of the original concentrate before roasting.

Various small scale experiments were tried on the chloridizing of the residues from the first leaching; 50 lb. were also sent to a plant where the Longmaid-Henderson process is in operation, and both tests gave satisfactory results. The liquor from the chloridizing plant would doubtless be reduced to argentiferous copper cement by iron, but 20 per cent of the original copper is involved. The sulphate liquor from the first leach could be precipitated on iron, or, with some limitations, would be suitable for electrolysis, regenerating the acid. It would seem possible to figure out a simple cementation plant, considering electrolysis as a competitor, on the basis of relative profit and not of necessity.

F. N. FLYNN, in discussing the paper, states that at Clifton experiments are being conducted to leach flotation concentrates without preliminary roasting, thus making the electrolyte directly.

The chairman then called for a *General Discussion on Leaching*. F. S. SCHIMERKA discussed the leaching of mill tailings at Clifton. MR. WILLIAMS of the Calumet & Hecla discussed the ammonia leaching process at the said plant, where a 40,000,000-ton dump is being leached by means of a solution containing ammonia and ammonium chloride. E. P. MATHEWSON, on being questioned by MR. VAN ARSDALE regarding wooden and concrete leaching tanks, stated that for small installations the wooden tanks are more economical than the concrete ones.

September 20th at Bisbee, Arizona

This day was dedicated mainly to Mining and Geology. The mines of the Warren District at Bisbee were inspected. Accommodations for surface, underground and geological trips were made. This district is one of the live wires of Arizona, producing in the neighborhood of 170,000,000 lb. of copper a year. The ore mined is treated at the Douglas smelters of the Calumet and Arizona and the Copper Queen Consolidated Mining Co., with small shipments of lead-gold-silver and high-sulphur-low-copper ores to the El Paso, Tex., Globe, Ariz., and Hayden, Ariz., plants of the American Smelting and Refining Company and the International Smelting and Refining Co.'s plant at Miami, Ariz.

At the technical session on Mining and Geology, the following papers were read: "Geology of the Warren Mining District," by Y. Bonillas, J. B. Tenney and Leon Feuchere; "Comparative Friction Test of Two Types of Coal Mine Cars," by P. B. Liebermann; "Petrography of the Mount Morgan Mine, Queensland," by W. E. Gaby; "Stoping in the Calumet and Arizona Mines, Bisbee, Ariz.," by Philip D. Wilson; "Co-operative Effort in Mining," by Joseph P. Hodgson; and

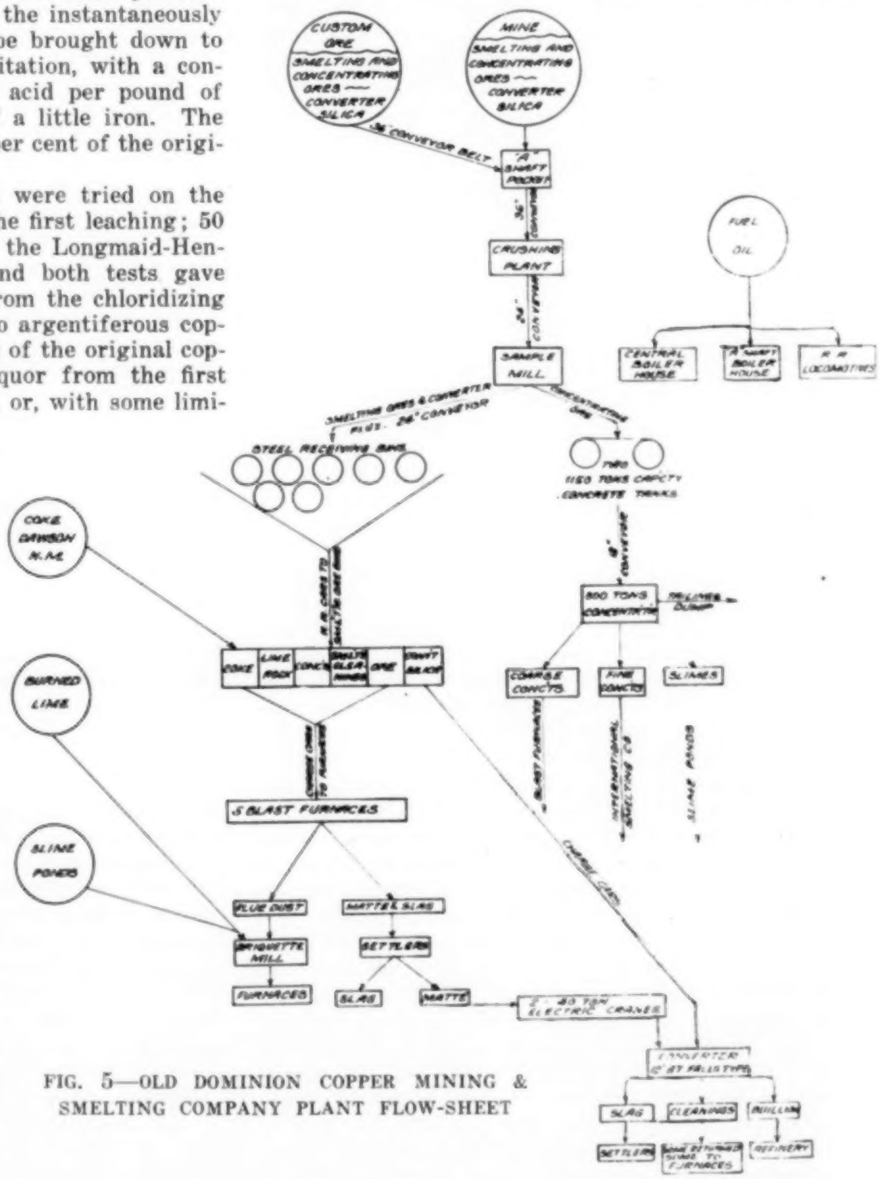


FIG. 5—OLD DOMINION COPPER MINING & SMELTING COMPANY PLANT FLOW-SHEET

"The Riffling of Diamond-Drill Cores," by W. R. Crane. The chairman of the session was G. F. G. Sherman.

A banquet was given to the members of the Institute at the Warren District Country Club, at which the following speeches were made: "Welcome to Arizona," by C. T. Knapp; "Arizona, Old and New," by L. D. Ricketts; "Arizona Present," by Walter Douglas; "The American Mining Congress," by Carl Scholz; "Why We Are Here," by Colonel Tillson, Twenty-second U. S. Infantry; and "Ave et Vale," by John Mason Ross. Philip N. Moore officiated as toastmaster.

September 21st at Globe

The first part of the schedule was to visit the **Mines and Reduction Works of the Old Dominion**

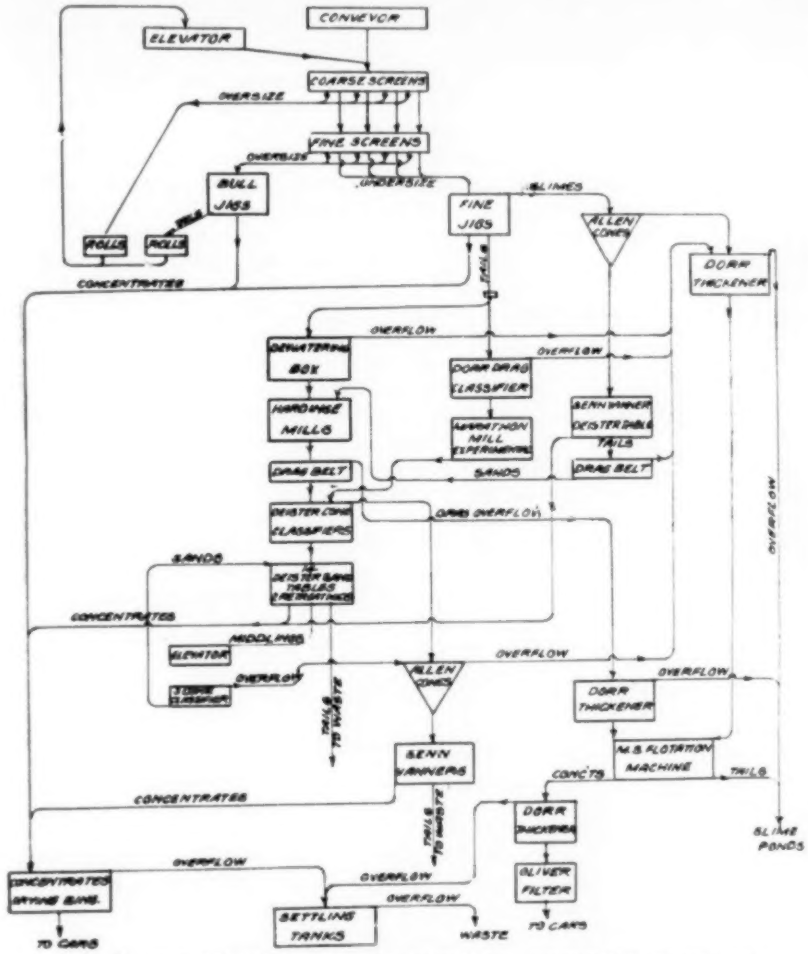


FIG. 6—OLD DOMINION COPPER MINING & SMELTING COMPANY CONCENTRATOR FLOW-SHEET

Copper Company. Fig. 5 is the flow-sheet of the plant, and Fig. 6 that of the concentrator plant. The crushing plant consists of two No. 7½ gyratory crushers, one for smelting ore and one for concentrating ore; one 48-in. Symons disk crusher and two 36-in. Symons disk crushers; one 8 ft. x 5-ft. trommel and one 10 ft. x 5-ft. trommel, both having circular 1-in. holes. The sampling mill is of the Vezin type, 100 tons of ore yielding a sample of 16 lb.

The concentrator equipment consists of shaking screens, jigs, 3 Woodbury classifiers and jigs, two Traylor rolls 42 in. x 16 in., for coarse crushing, and five 8 ft. x 36-in. Hardinge pebble mills and one 8 ft. x 48-in. Marathon mill for fine crushing. The other machines used are Deister tables, Senn vanners, coarse concentrating vacuum tanks, and a Blaisdell excavator. The flotation plant contains 300-ton, 16-box mineral separation machine and two Oliver filters.

The smelter comprises one furnace 19 ft. 3 in. x 44 in. and four furnaces 16 ft. 6 in. x 44 in. The average tons charge per furnace per day is 282. The per cent coke to charge is 12.85. The average blast pressure is 21.5 oz., and the matte fall is 18.33 per cent. The converters used are of the 12-ft. Great Falls type. The arrangement of the smelter plant is clearly shown in Fig. 5.

Flotation and Concentration

The afternoon session was held on Flotation and Concentration. The acting chairman was W. J. MILLS. The first paper presented was that by DAVID COLE, entitled, ***The Advent of Flotation in the Clifton-Morenci District, Arizona.*** The article treats of the gradual development of the flotation process and the use of the C-B flotation machines. The C-B flotation machine is a development of the simple tube-grate cell, of which Fig. 7 gives an illustration. Experimental work on this single cell was so satisfactory that it was decided to build a three-stage machine to have a capacity of 400 tons per day. After some mechanical changes, such as overcoming the corrosive action of the water and the clogging up of the air ducts, the machine was found to work satisfactorily on a large scale. A longitudinal section of the C-B flotation machine is given in Fig. 8. Tests were run between this new type of cell and the Callow cell, and it was found that it would handle much larger amounts of material. It also makes large volumes of very rich froth. The paper was not discussed.

The second paper on the program was *History of the Flotation Process at Inspiration,* by R. GAHL. This paper is printed in full in the September 15th issue and in the present issue of this journal. A lively discussion followed by Messrs. LAIST, SCHIMERKA, MORSE, COLE, HANDY, CAMPBELL, RICKETTS, COTTRELL and RUGGLES. Dr. GAHL first extended the paper to the present time, mentioning that oxidized copper and sulphides might be converted to carbonates and then these floated, but at present the method is not economical. Limestone may be used to precipitate soluble copper. Tailing middlings may be floated.

MR. LAIST communicated that the choice of a flotation machine depends on the locality where it is to be used. Pneumatic machines usually work better in an alkaline solution, while the non-pneumatic type is better for acid solutions. The impeller machine for acid solutions requires an emulsifier. The impeller machine gives a tougher froth. The power factor is the main criterion for the selection of an impeller or pneumatic flotation machine.

MR. COLE wished to know if it were beneficial to remove the classifiers. DR. GAHL replied that the expense of operating a classifier is low, and it requires a small settling capacity for the table tailings, and the

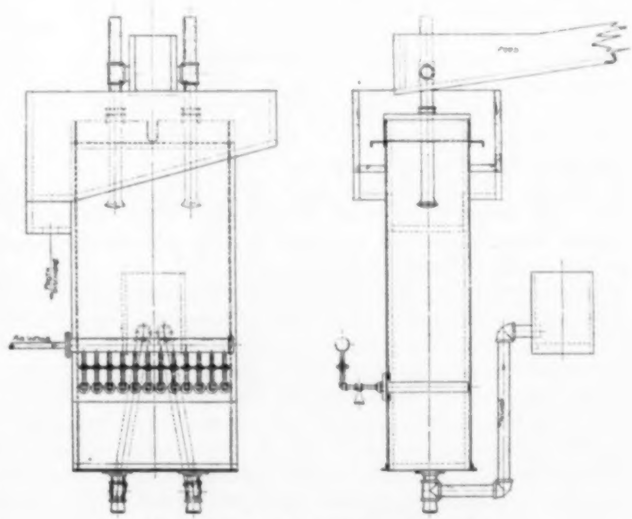


FIG. 7—SIMPLE TUBE-GRATE CELL

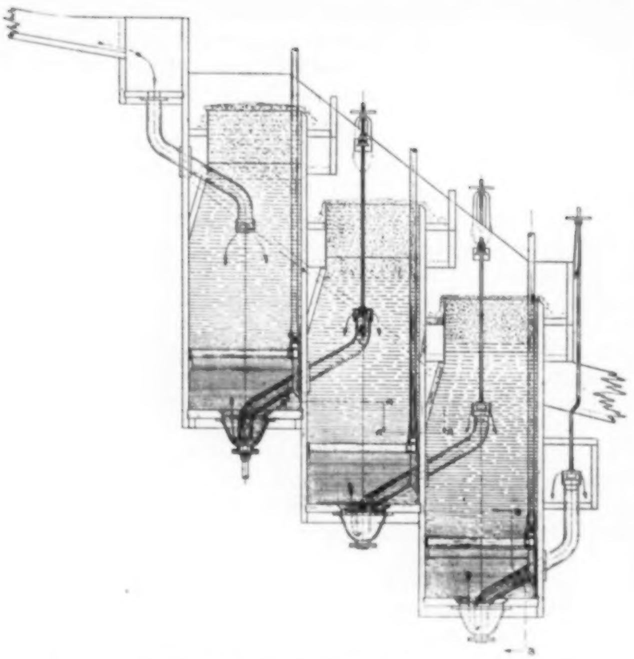


FIG. 8—LONGITUDINAL SECTION OF C-B FLOTATION MACHINE. THREE CELLS IN SERIES

water may be reclaimed at the foot of the mill at a low cost. Dr. Gahl believes that a hydraulic classifier pays for itself. Mr. Cole asked whether it would be an advantage to avoid the separation of the sands and slimes. Dr. Gahl replied that a better sand treatment is obtained by removing the sand first. E. P. Mathewson confirmed Dr. Gahl's statement.

In a communicated discussion of this paper by David Cole of El Paso, Tex., published in the October "Bulletin" of the Institute, some interesting data are given on the milling problems which came up during the flotation experiments. Prior to the use of flotation the greatest problem was the reduction of the losses of sulphides in the slime. The Inspiration Company in 1912 began to study its milling problems, and plans were drawn for a 7000-ton per day gravity process plant. It was at this time that experiments on flotation promised to solve the slime problem. A "pilot" mill was built to treat 600 tons of ore per day, pending the completion of the milling plant. It was in this test mill that the flotation problems, grinding problems, power consumption, use of water, and many other questions were threshed out. The "pilot" mill paid for itself from the production which it turned out. Many different kinds of crushers, pulverizers and mills were tried out. The Marcy type of ball mill was finally adopted, although the conical type steel-ball mill vs. the Marcy type steel-ball mill did not receive a tryout, contrary to general opinion. Whether or not the Hardinge machine, when built as a ball mill with the required strength, type of lining, size of feed and discharge opening would do as well, was not determined, owing to the pressure of time.

The third paper on the topic of flotation was: *Some Miscellaneous Wood Oils for Flotation*, by R. C. Palmer, Glenn L. Allen and O. C. Ralston. These oils were tested on three different ores: Ore A was from the Arthur Zinc Mining Co., near Ruby Valley, Nev., and consisted mainly of galena, sphalerite and quartz minerals. Ground quartz was mixed with this ore to make it sufficiently low grade. Ore B was the heavier sulphide ores from Cripple Creek, Colo., consisting of siliceous material, some pyrite, sylvanite, calaverite, and some other tellurium minerals. Ore C was the milling ore of the Utah Copper Co., from the mine at Bingham, and essentially copper minerals such as chalcopyrite, cupriferous pyrite, etc. Each ore was subjected to an acid test, an alkaline test, and a test using neutral water.

The oils investigated were as follows: No. 23 was an authentic commercial pine oil, specific gravity 0.9385, and having a sulphonation residue of 0.8 per cent. No. 11 was a commercial wood oil obtained from the destructive distillation of maple and birch wood, having a specific gravity of 0.934 at 21 deg. C. No. 18 was hard wood tar obtained by the dry distillation of equal portions of beech, birch and maple wood. Its composition is 12 per cent pyroligneous acid, 8 per cent wood oil, 42 per cent wood creosote oil, and 38 per cent wood pitch. The specific gravity at 21 deg. C. was 1.067. No. 15 is the tar left on completely distilling off the pyroligneous acid of beech, birch and maple wood. The tarlike substance left is heavy, non-volatile and viscous, and has a specific gravity of approximately 1.4. It is 50 per cent soluble in water, the rest dissolving in the pyroligneous acid. No. 16 is a 15 per cent water solution of the water-soluble part of No. 15, and has a specific gravity of 1.061 at 21 deg. C.

Table II—Tests on Ore A in Neutral, Acid and Alkaline Solutions with Different Oils

Analysis Head: Lead, 3.4 Per Cent; Zinc, 4.74 Per Cent

Oil No.	Character of Oil	Remarks	Total Time, Min.	Total Oil, Lb. per Ton	Total Acid, Lb. per Ton	Total Alkali, Lb. per Ton	Lead: Per Cent	Lead: Per Cent Extraction	Zinc: Per Cent	Zinc: Per Cent Extraction
23	Pine oil........	Concentrate	10	0.375	....	....	55.9	53.1	12.4	62.2
		tailing	10	0.375	....	....	1.6	....	2.3	....
			10	0.375	11.14	....	32.3	87.9	37.9	78.2
			10	....	3.36	....	0.4	....	1.1	
			15	0.375	....	8.0	8.0	89.5	25.5	79.1
			10	....	....	2.0	0.4	....	4.4	
11	Hardwood "wood oil"..........	....	17	1.11	....	....	57.2	92.6	20.4	58.2
			10	0.18	....	....	0.3	....	2.3	
			16	0.94	3.68	....	37.9	88.7	34.2	72.6
			15	0.17	3.68	....	0.4	....	1.4	
			15	1.29	....	4.0	48.0	97.2	32.0	64.8
			5	....	....	....	0.1	....	1.8	
18	Crude hardwood "settled tar"..	....	17	1.25	....	....	48.6	97.2	28.0	68.4
			3	....	....	....	0.1	....	1.7	
			19	1.24	3.68	....	37.7	98.2	33.4	76.5
			6	....	....	....	0.1	....	1.2	
			20	1.70	....	2.0	48.7	98.0	27.9	63.4
			4	....	....	....	0.1	....	1.9	
15	"Dissolved hardwood tar"....	....	20	1.44	....	....	59.2	79.4	16.2	30.2
			7	....	....	....	0.7	....	3.5	
			15	1.44	5.52	....	32.8	86.7	13.0	60.8
			10	0.72	3.68	....	0.4	....	1.9	
			20	1.44	....	4.0	66.7	73.0	38.1	30.3
			8	....	....	....	1.0	....	3.4	
16	Water solution of No. 15.....	....	13	1.80	....	....	55.1	90.2	22.0	43.7
			5	....	....	....	0.4	....	2.9	
			19	1.80	7.36	....	30.3	92.2	40.5	77.2
			4	....	....	....	0.3	....	1.2	
			19	1.80	....	4.0	53.7	77.4	23.3	44.7
			4	....	....	....	0.8	....	2.9	
14	Crude hardwood pyroligneous acid..........	....	20	14.00	....	....	54.3	86.2	22.7	51.5
			3	....	....	....	0.5	....	2.6	
			15	14.00	5.5	....	29.5	72.2	41.5	70.0
			5	....	....	....	1.0	....	1.5	
			17	12.0	....	4.0	62.0	54.8	9.8	42.7
			6	....	....	....	1.5	....	3.4	
12	Tar-free hardwood pyroligneous acid....	....	13	20.0	3.68	....	23.5	42.7	31.7	41.4
10	Crude softwood pyroligneous acid.........	....	17	10.0	....	....	53.8	73.3	23.9	41.3
			13	4.75	....	....	1.0	....	3.0	
		No	18	12.0	3.68	....	31.6	64.7	35.2	57.3
		cleaner	7	4.00	....	....	1.3	....	2.2	
		test	12	16.00	....	4.0	40.1	57.8	17.9	15.0

No. 14 was a semi-commercial pyroligneous acid obtained from maple. Its specific gravity was 1.036 at 21 deg. C., and it had a composition of 9.7 per cent dissolved tar, 4.8 per cent wood alcohol, and 11.9 per cent acetic acid. No. 12 was a commercial pyroligneous acid obtained by distilling birch and maple, the tar having been removed by distillation. The specific gravity of this oil was 1.008 at 21 deg. C., and it contained 3.1 per cent wood alcohol and 5.9 per cent acetic acid. Oil No. 10 was commercial pyroligneous acid, obtained by the distillation of Southern yellow pine. Its specific gravity was 1.034 at 21 deg. C., and contained 1.8 per cent alcohol, 2.85 per cent acid, and 7 per cent dissolved tar.

The results obtained by the authors are best reproduced in the tabular form given by them, as the work is of practical significance. This is done in Tables II, III, IV, V.

The last paper read was the one by Frederick Laist and Albert E. Wiggin, entitled: *Flotation Concentration at Anaconda, Mont.* Part I covers all the experimental work comprising tests with standard Minerals Separation machines, tests with mineral separation machines of the sub-aeration type and tests with the Callow pneumatic machine. Tests on various kerosene sludge acid oils and creosote oils were made and the blankets for the Callow cell were tested. It was concluded that the Minerals Separation machine was best adapted for the flotation work at Anaconda.

Part II gives a description of the remodeled concentrator as adapted to flotation. The remodeled concentrator consists of eight sections, each of 2000 tons per day capacity, giving a total of 15,000 tons per day, allowing for shutdowns and repairs.

Part III is a description of the slime flotation plant. It consists of twenty Minerals Separation machines and five Dorr thickeners to dewater the concentrates. The plant is designed to treat approximately 2000 tons of current slime and 1000 tons of pond slime.

Part IV describes the flotation concentrates dewatering plant, which consists of five Dorr thickeners for the flotation concentrates and another five for the slime. The pulp is delivered to the thickeners by means of baffle boxes, which reach nearly to the rake arms of the thickener. These boxes are surrounded by a second baffle box extending about 18 in. below the surface of the water. These baffles take care of much of the froth. The capacity of the flotation concentrate tanks is 200,000 to 250,000 gal. of pulp per 24 hours. When treating table concentrates these same tanks have a capacity of 1,000,000 gal. of pulp per 24 hours.

The paper was discussed by the following: O. C. RALSTON, E. P. MATHEWSON, DAVID COLE, RUDOLF GAHL, A. L. BLOMFIELD, Mr. CRAMER, F. M. HANDY, A. P. WATT and B. B. GOTTSBERGER. Some of the most important questions asked were: Dr. GAHL: Why is it that in certain places acid may be used on chalcocite as at Anaconda, while in Arizona this practice would be detrimental? This could not be answered. Mr. BLOOMFIELD: What is the effect of alkali? Mr. CRAMER: The use of sodium hydroxide flattens the froth, it cuts down the water used in the launders and makes the product easier to handle. At the Old Dominion it is essential to use sodium hydroxide as it increases the yield. O. C.

TABLE III—TESTS ON ORE B IN NEUTRAL, ACID AND ALKALINE SOLUTIONS WITH DIFFERENT OILS

Analysis Head: Gold, 0.608 Oz. per Ton; Iron, 5.2 Per Cent

Oil No.	Total Time, Minutes	Total Oil, Lb. per Ton	Total Acid, Lb. per Ton	Total Alkali, Lb. per Ton	Gold* Oz. per Ton	Gold* Per Cent Extraction	Iron* Per Cent	Iron* Per Cent Extraction
23	21	0.375	0.00	0.0	4.50	81.5	8.0	10.2
	21	0.575	3.68	0.0	6.42	78.7	9.0	16.5
	21	0.375	0.00	1.0	4.76	79.7	8.2	9.9
11	24	1.11	0.00	0.0	4.72	82.5	8.5	31.9
	22	1.11	3.68	0.0	6.12	75.8	17.2	41.1
	23	1.11	0.00	4.0	5.64	82.3	13.4	14.8
18	22	1.8	0.00	0.0	10.34	78.2	13.2	17.7
	21	1.5	3.68	0.0	11.52	78.0	14.3	19.6
	22	1.5	0.00	1.0	11.60	81.2	13.1	6.2
15	23	2.88	0.00	0.0	5.06	82.3	5.7	0.0
	21	2.88	3.68	0.0	13.80	74.8	9.6	11.8
	21	2.88	0.00	1.0	5.80	76.0	7.4	6.2
16	21	2.4	0.00	0.0	10.10	81.3	8.6	31.5
	21	2.4	3.68	0.0	12.60	81.2	.....	0.0
	21	2.4	0.00	1.0	7.88	78.7	11.7	27.3
14	21	12.0	0.00	0.0	5.42	79.1	9.2	32.5
	22	12.0	3.68	0.0	7.22	81.7	12.0	40.3
	19	12.0	0.00	1.0	7.28	78.7	12.1	26.9
12	15	18.0	0.00	0.0	5.88	76.0	7.7	32.3
	20	20.0	3.68	0.0	6.76	81.7	15.0	12.8
	15	24.0	0.00	1.0	9.44	77.0	6.9	14.0
10	23	16.0	0.00	0.C	5.40	88.7	6.1	40.8
	21	16.0	3.68	0.0	4.98	79.6	6.0	41.2
	24	16.0	0.00	1.0	6.10	79.2	6.5	16.7

*In concentrate samples.

TABLE IV—TESTS ON ORE C IN NEUTRAL, ACID AND ALKALINE SOLUTIONS WITH DIFFERENT OILS

Heads: Copper, 1.58 Per Cent

Oil No.	Total Time, Minutes	Total Oil, Lb. per Ton	Total Acid, Lb. per Ton	Total Alkali, Lb. per Ton	Copper* Per Cent	Copper* Per Cent Extraction
23	17	0.375	0.00	0	3.83	
	16	0.375	7.36	0	8.61	28.7
	17	0.375	0.00	4	1.53	
11	20	0.92	0.00	0	15.95	29.3
	21	1.48	7.36	0		
	21	1.29	0.00	6	16.15	32.6
18	20	1.8	0.00	0	16.45	51.2
	20	1.5	7.36	0	2.48	
	20	1.2	0.00	4	22.27	68.2
15	21	1.44	0.00	0	5.84	4.3
	21	1.44	7.36	0	2.77	
	23	1.44	0.00	4	18.17	23.1
16	17	2.1	0.00	0	4.50	33.6
	18	2.7	7.36	0	1.72	5.6
	23	2.4	0.00	8	7.94	3.9
14	20	5.0	0.00	0	2.29	
	18	5.0	7.36	0	1.43	
	19	7.0	0.00	4	12.90	13.5
10	19	8.0	0.00	0	1.24	
	19	10.0	7.36	0	1.43	
	12	8.0	0.00	7	2.29	25.3

*In concentrate samples.

TABLE V—SCREEN ANALYSES

	Opening Mm.	Mesh	Weights Per Cent	Assays Pb, Per Cent	Assays Zn, Per Cent
Ore A					
Through	0.589	28	100.00		
On	0.417	35	0.43	0.00	0.00
On	0.208	65	12.88	0.05	0.98
On	0.147	100	34.46	0.07	1.37
On	0.104	150	23.76	0.07	2.24
On	0.074	200	10.50	2.19	6.46
Through	0.074	200	17.75	19.08	14.60
Ore B					
Through	....	200	100.00		
Ore C					
Through	0.295	48	100.0		
On	0.208	65	2.2	1.58	
On	0.147	100	16.7	1.58	
On	0.104	150	16.0	1.82	
On	0.074	200	53.3	1.46	
Through	0.074	200	11.8	1.73	

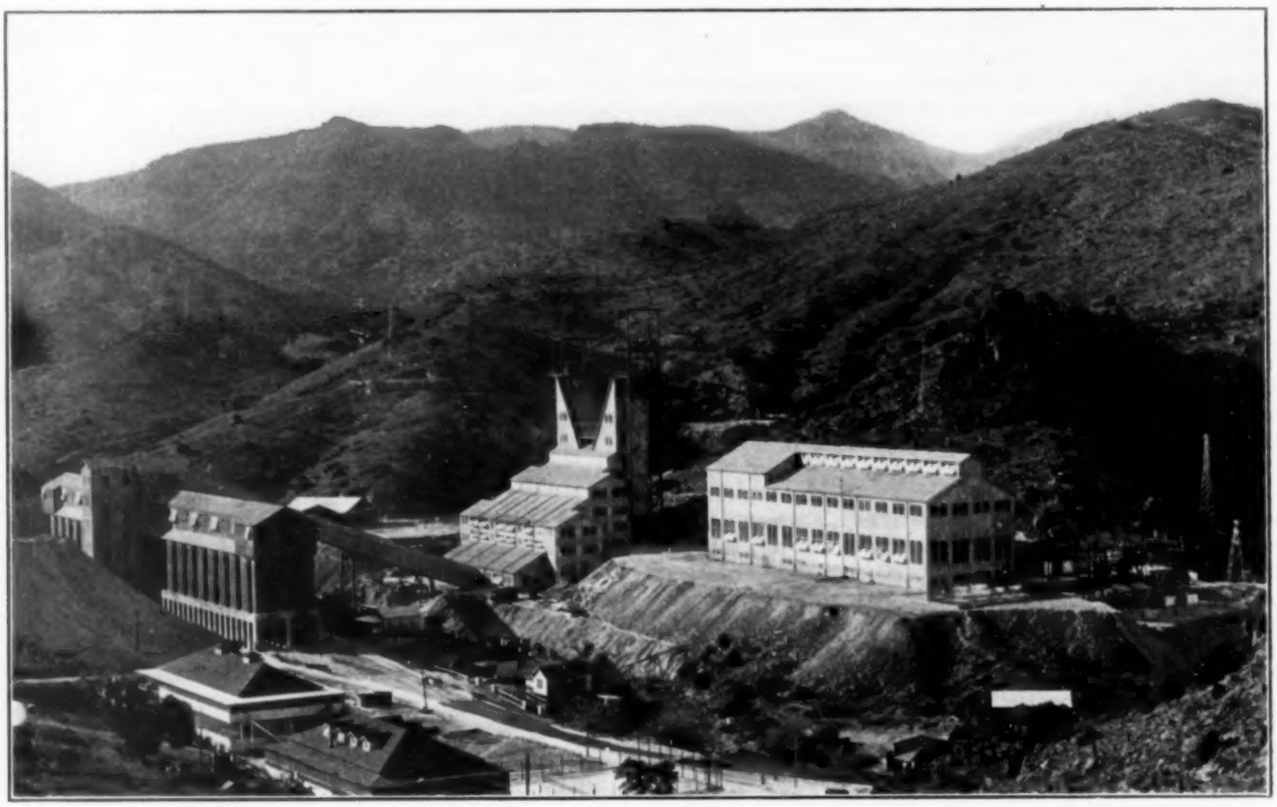


FIG. 9—INSPIRATION MINING PLANT

RALSTON: An addition of alkali gives a slower settling of the slimes. Alkali acts as a deflocculent on the slimes, liberating the values. Mr. Ralston then asked several very important questions, some of which were answered while others had to go without an explanation, but they started the members thinking along those lines. First, What is the effect of dilution by water on the mineral contained? Dr. GAHL: gives cleaner concentrates, but the concentrates are harder to obtain and uses more oil. Second, What determines the amount of oil used? Is there a definite ratio of the water to the oil? This remained unanswered. Third, Are colloidal ores harder to treat than granular ores? Both Mr. MATHEWSON and Dr. GAHL claim that colloidal material is more difficult to treat. Fourth, Would it be possible to treat the colloids and obtain a flotation product? Fifth, How

FIG. 10—INSPIRATION CONCENTRATOR

much colloidal material would be permissible? These last two questions remained unanswered. F. S. SCHIMERKA mentioned that it would be of great value to determine the density of the pulp when oil is added and when the pulp is diluted. This might lead to some conclusions as to the amount of oil to be added.

Mining and Smelting

The evening session was on **Mining and Smelting.** The chairman was P. G. BECKETT. Most of the papers were on straight mining subjects with the exception of that by W. A. SCHMIDT, which was an illustrated lecture on the Cottrell dust collecting system as used at the International Smelting Company and at a cement works in California. The effect produced by the system was shown experimentally in an interesting manner.

The mining papers read were: "The Block Method of Top Slicing of the Miami Copper Company Mine," by E. G. Deane; "Stoping Methods of Miami Copper Company," by D. B. Scott; "Mine Fire Methods Employed by the United Verde Copper Company," by R. E. Tally; "Ore-Drawing Tests and the Resulting Mining Methods of Inspiration Consolidated Copper Company," by G. R. Lehman, and "Cost and Extraction in the Selection of a Mining Method," by C. E. Arnold.

September 22d at Globe, Ariz.

The last day of the meeting proper was one of greatest interest. The morning was spent at the **Mill of the Inspiration Consolidated Copper Company and at the Reduction Works of the International Smelting and Refining Company.** It is a well-known and admitted fact that the mill of the Inspiration is the one most up to date at present. Figs. 9 and 10 are views of the Inspiration mine plant and concentrator. In the mine plant the striking feature is the use of labor-saving devices. Wherever possible mechanical contrivances are employed in place of manual labor. This is the case with the hoist and the ore-distributing system. There is something nearly uncanny about the plant, as one observes the machines working away and practically no human being in the vicinity.

The mill proper needs no further elucidation as the paper by Dr. Gahl gives the full description. The accompanying Fig. 11 gives the complete flow-sheet, which is self-explanatory. The one striking feature of the whole plant is its cleanliness. One seems to feel instinctively that every effort was put forth by everyone to make this plant a landmark in the field of the copper metallurgy.

A good companion to the mill of the Inspiration is the reduction plant of the International Smelting Company, a view of which is

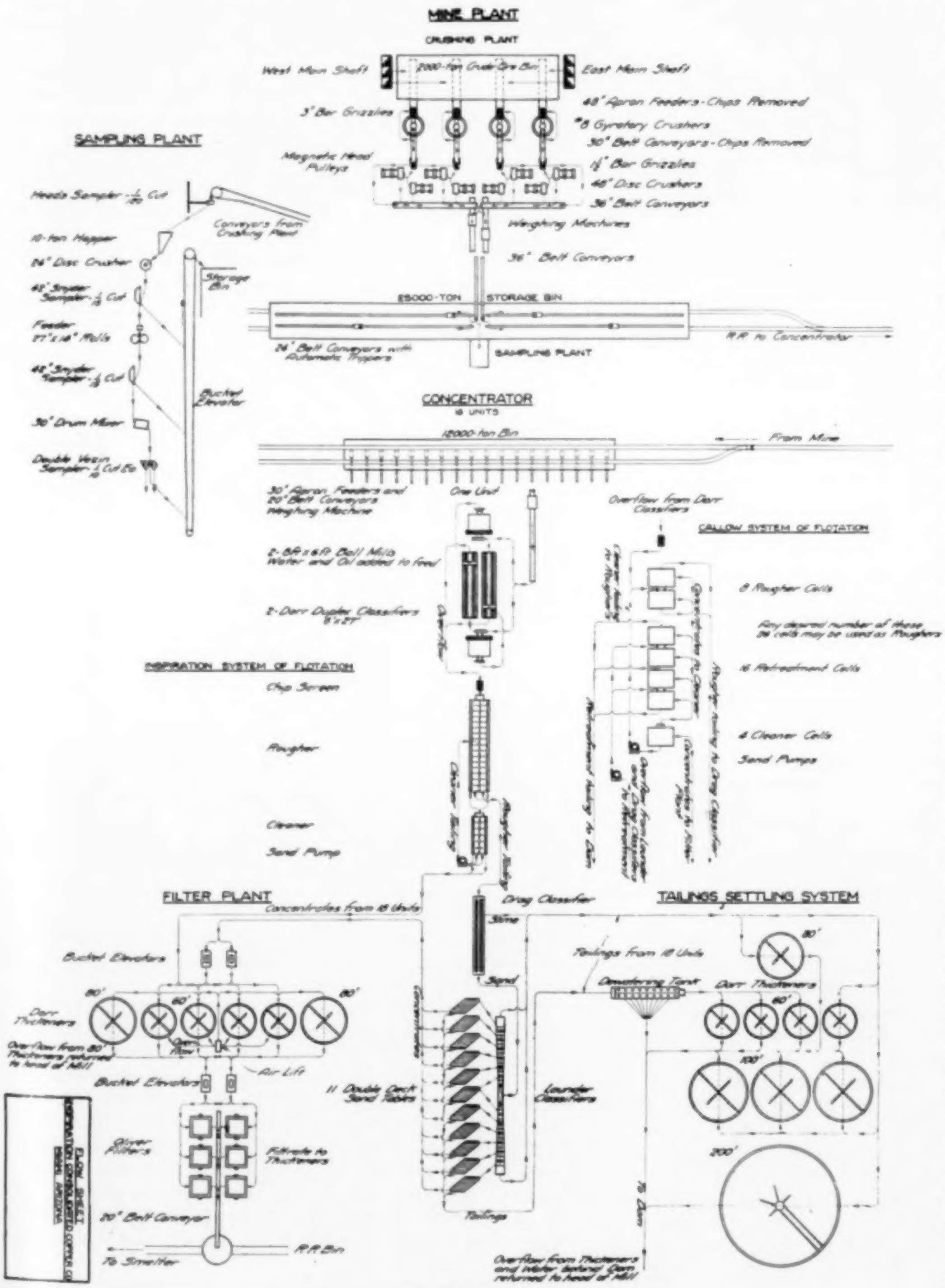


FIG. 11—FLOW-SHEET OF INSPIRATION

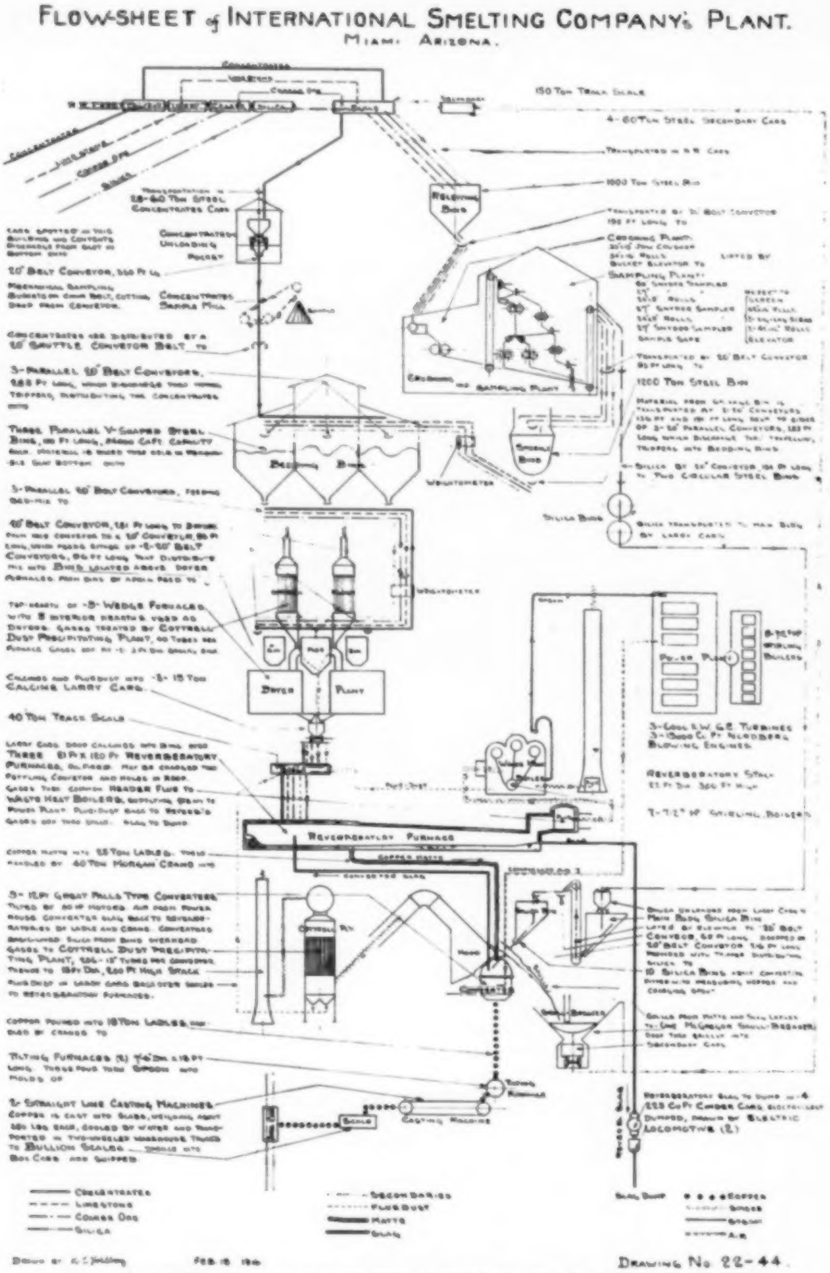


FIG. 12—FLOW-SHEET OF INTERNATIONAL SMELTING COMPANY'S PLANT, MIAMI, ARIZONA

given in Fig 12. The plant consists of a drying plant, a reverberatory plant and a converter plant. No blast furnaces are used. The Wedge furnaces used are not employed for roasting but merely for drying. The matte produced in the reverberatory furnace goes to the converter department and is blown to blister copper. The plant is very compact and is simplicity itself. Fig. 12 is the flow-sheet of the smelter.

After enjoying a luncheon at the clubhouse of the Miami Copper Company, the **Mill of the Miami Copper Company** was visited. While the mill of the Inspiration is undoubtedly newer and more up to date, one looks upon the mill of the Miami Copper Company with awe and admiration for a great deal of the development of the flotation process was conducted at this mill and the Inspiration only proves the excellent work which was done at the Miami, for it was no little matter to improve on the Miami mill. Some data may prove of interest. The dry tons milled from January to June, 1916, were 859,485, or 4722 tons per day. The copper in the feed averaged 2.09 per cent, of which 0.32 per cent was oxidized and 1.77 per cent was present at sulphide. The percentage of copper in the concentrates was 41.74. The total copper in the tailings amounts to 0.56 per cent, of which 0.30 per cent is oxidized and 0.26 per cent is present as sulphide. The recovery of copper is 74.06 per cent.

Fine Grinding

The last technical session was on fine grinding. The session was presided over by B. B. GOTTSBERGER. The first paper offered was by CHARLES LEGRAND on the "Power Plant at Burro Mountain Copper Company." The discussion was conducted by Messrs. GOTTSBERGER, LANGDON and KIDDER.

The second paper was: "Comparative Test of the Marathon, Chilean and Hardinge Mills," by F. G. BLICKENSDERFER. The tests were run for several months under actual milling conditions. The Chilean and Marathon mills ran simultaneously for 63 days. The Hardinge mill ran for the first 30 days with an old lining, which was then replaced by a new one. The average results of the Hardinge and the Chilean mills for the 63 days will be compared with the Marathon mill. The tests were made on the Marathon mill. In test No. 1 the feed was the same as for the Hardinge and the Chilean mills. Some time elapsed between Marathon tests No. 1 and No. 2, to determine the best method for handling heavy loads. Three shovel wheels were installed to remove all slimes and the greater amount of water. The tonnage per unit was reduced to 500 tons per day instead of 750. Subtracting the weight of concentrates produced in primary table concentration, and the weight of slimes recovered by the shovel-wheels preceding the Marathon mill, a net weight of 430 tons per 24 hours was obtained. The total recovery of the unit under these conditions was practically the same as the second unit operating three Chilean mills and this paved the way for a heavy tonnage on the Marathon mill.

The results obtained are: that under the conditions of these tests the Marathon mill is far superior to the Hardinge and the Chilean mills in grinding efficiency. Of the Hardinge and the Chilean mills the Chilean is superior to the Hardinge.

On the basis of these results two new mills have been ordered by the Detroit Copper Company at Morenci, Ariz., being 8 ft. long and having a diameter of 4 ft. with the following improvements: The feed scoops have three channels, the entrance to each channel being 108 sq. in., the scoops being placed at the head end of the mill; sectional liners for the head and solid circular ones for the tail end; rigid base, with no tilting arrangement; non-spiral, solid roller bearings; the driving gear is attached to the tail end of the shell, the pulley being supported rigidly by having its bearings set solidly on a separate concrete base.

A lively discussion by Messrs. GOTTSBERGER, KILIANI,

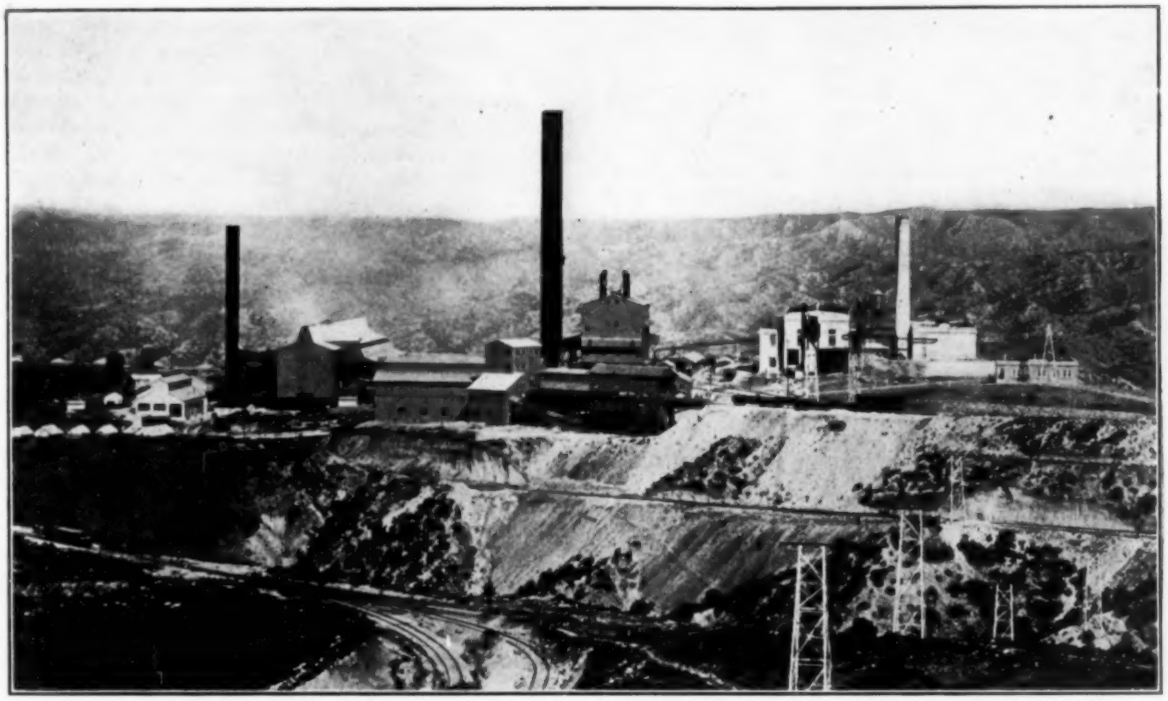


FIG. 13—REDUCTION WORKS OF THE INTERNATIONAL SMELTING COMPANY

FRANKE, MERRILL and THAYER followed this paper. Mr. GOTTSBERGER said that the efficiency of mills is increased by replacing pebbles by steel balls. Concerning the sliming Mr. BLICKENSDERFER found that the Hardinge slimed slightly less total feed and slightly more mineral. On the other hand, Mr. KILIANI, in a large number of tests, observed just the reverse. Mr. THAYER: What is the action in the Marathon mill, grinding or crushing alone or both? Mr. BLICKENSDERFER: Both In the Marathon mill there is no spherical contact, but simply linear contact.

A banquet was given in the evening on returning from Miami to Globe in the auditorium of the high school. The toastmaster was S. J. JENNINGS. The evening was enlivened by the following speakers: JOHN E. BACON, "Safety First"; L. D. RICKETTS, "The Growth of the Globe District"; E. P. MATHEWSON, "Why the Young Engineer Should Join the Institute," and finally F. G. COTTRELL, "The Utilization of Waste Products." Further charm was given to the evening by the music rendered by the local orchestra.

This officially terminated one of the most interesting meetings in the history of the Institute. On the 23d automobiles took the party over the Apache Trail, past the Roosevelt Dam, a marvel of engineering, to Phoenix, from where the party left the same evening to enjoy the beauties of the Grand Cañon of the Colorado. Here was the parting of the ways, each one going to his own home and destination, but all carrying with them a feeling of thanks and admiration for Arizona and her people.

Purification of Kaolin.—Some interesting data on experiments with American kaolin were given in a paper presented by CHARLES L. PARSONS at the colloid symposium of the New York meeting of the American Chemical Society. The large deposits of kaolin in South Carolina and Georgia could not heretofore be used in the pottery industry for white ware, as the titanium and iron oxides in the clay discolored the ware. The Bureau of Mines, in investigating this kaolin, found that a small amount of sodium hydroxide deflocculated the colloids so that the clay readily remained in suspension in water for a long time, allowing the small particles of heavier minerals to be separated out. As a result, co-operative experiments were conducted with the Georgia Kaolin Company, near Macon, Ga., and a plant built for purifying kaolin in accordance with the facts discovered in the laboratory. As a result, many tons of kaolin were purified at an almost nominal cost. The pure china clay so produced was investigated by one of the bureau's experts in two large potteries in the State of Ohio, and it has been definitely shown that these kaolins, at a cost of a few cents a ton, can be converted from a material selling for $4.50 a ton to a material easily marketable at twice this figure. Furthermore, white tile made from this kaolin, mixed with American feldspar in proper proportions, has been produced of a greater degree of whiteness and a greater breaking strength than the best tile previously produced from English china clay and Cornwall stone. The purified kaolin has also been found to be applicable to white china ware, thus replacing a large part of the English China clay. America should, accordingly, be entirely independent of the importation of foreign material for the white ware industry.

The **Jewell Polar Company,** manufacturers of Jewell Polar water-distilling and filtering systems, have issued a new, thirty-two page catalog, describing the new improvements in Jewell Polar stills for drinking water.

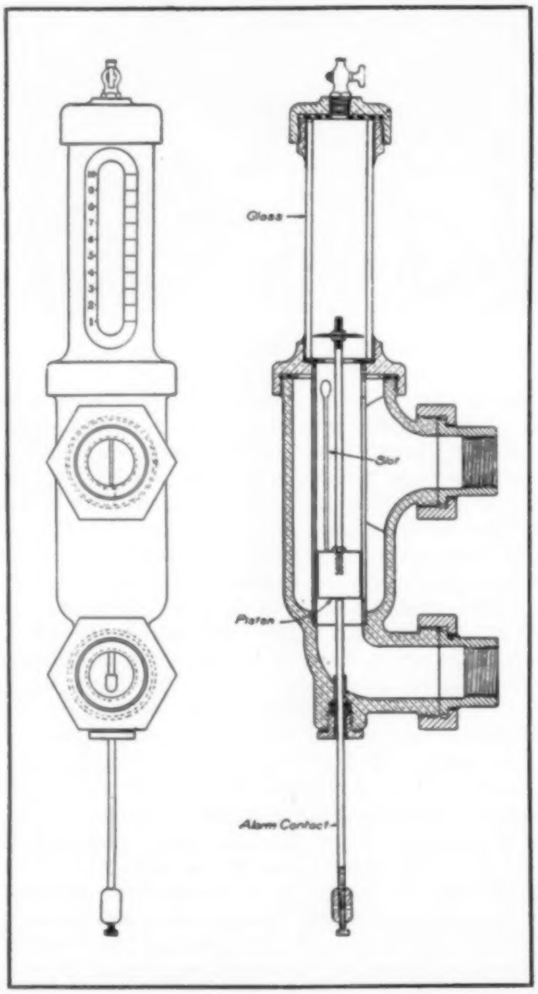
Burgess & Long, chemical engineers of Columbus, Ohio, will open, on November 1, a branch office and laboratory in Chattanooga, Tenn.

New West Virginia Acid Plant.—The Fairmont Chemical Company, Fairmont, W. Va., will erect on Tygart Valley River a sulphuric acid plant with a capacity of 10,000 tons per annum, to be operated by the multiple-tangent system. An auxiliary plant for the manufacture of nitric acid will also be erected. It is estimated the plant will cost from $75,000 to $85,000. The building will be constructed of steel and concrete and will be fire-proof. The plans were by Ludwig A. Thiele, Columbus, Ohio, who will be the engineer in charge of construction.

A New Flow Meter for Liquids

A flow meter designed for indicating the flow of liquids in pipes, known as the Vaughan flow meter and sold by the Spray Engineering Company, Boston, Mass., is shown in cross-section in the accompanying illustration. The instrument, which has several interesting features, consists of a cylindrical chamber with suitable pipe connections enclosing a slotted tube through which the liquid must pass.

Enclosed in the slotted tube is a piston which, as the liquid is turned on, is carried up until the exposed area of the slots is sufficient to allow the flow of the liquid up to the capacity of the indicator. An index is attached to the upper end of the piston rod, which extends up into a glass tube at the top of the cylindrical chamber. The glass tube is encased in a protecting cover, corresponding to the rise or fall of the piston, to be noted. A scale on the side of the case enables the operator to determine accurately the amount of flow in gallons per minute.



GENERAL VIEW AND CROSS-SECTION OF FLOW METER

An electric contact consisting of an adjustable brass rod set through an insulated stuffing box at the bottom of the chamber can be connected to a lamp or bell, calling attention when the flow has fallen below a fixed minimum. Contact is established immediately the piston rests on the brass rod. The desired flow of the liquid may thus be secured within the capacity of the instrument. The flow is directly proportional to the area of the slots in the enclosed tube, or to the rise or fall of the piston.

Under test the indicator gives practically a straight line calibration over a large range, and the loss of head in operating the instrument has been found to be negligible, not exceeding 0.004 lb. per square inch with a capacity of 15 gal. per minute. The indicator may be used with screens for dirty water, and can readily be cleaned by unscrewing the top and slipping out the slotted tube and glass.

The Messerschmitt Process for the Production of Hydrogen

By Harry L. Barnitz, Ph. G.

The Messerschmitt process for the production of hydrogen prior to the European war was not generally known. In a limited way it was known to a few in this country. Since the war many great improvements have been made in this process.

Claims made by Dr. Messerschmitt that his process was superior to all known methods for large productions of hydrogen were accepted in some quarters, but he was not wholly supported at the time he made these statements, due to the fact that only one or two installations were made in Germany and they had not been operated for a period of sufficient length to bear out his claims. More exact information is available now from many plants installed since the war in Germany and other countries. The following article is based on information received from Germany at a very recent date direct from Dr. Anton Messerschmitt.

The military authorities of Germany have adopted the Messerschmitt process for the production of hydrogen to the exclusion of all processes heretofore suggested and in use for installations of large production. Fourteen Messerschmitt plants at a cost of $20,000,000 are now being operated by the German War Department, having a capacity of 100 cubic meters to 600 cubic meters per hour. Several more plants are in the course of construction; one plant of two units of the Messerschmitt process is in operation in the United States. The hydrogen from this plant is used for hydrogenation of oils.

The production of hydrogen after the system of Dr. Anton Messerschmitt is based on the so-called iron contact method.

FIG. 1—HYDROGEN GAS WORKS AIR SHIP DEPOT, KOENIGSBERG

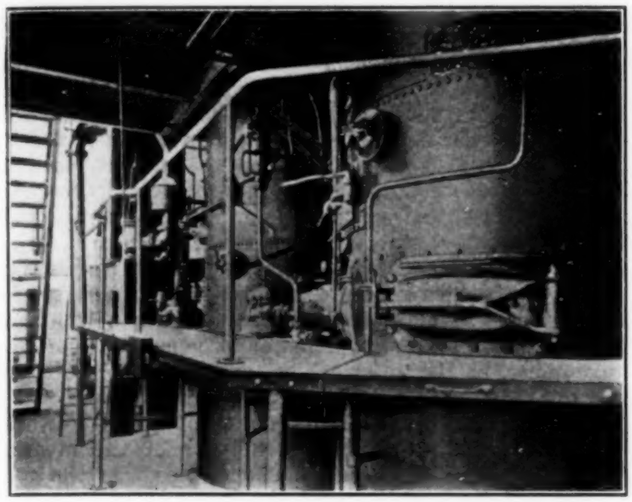


FIG. 2—HYDROGEN GAS GENERATOR, PHOTOGRAPH TAKEN BEFORE THE WAR

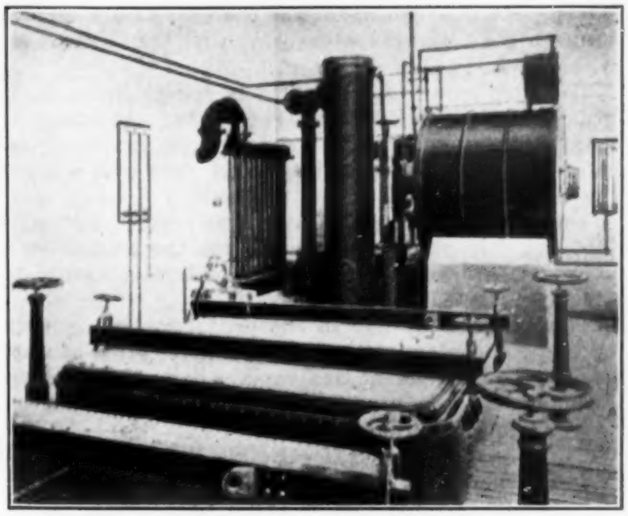


FIG. 4—PURIFIERS, FINAL CONDENSER AND GASMETER

This method is based on the fact that if steam is passed over red-hot iron it is decomposed into its elementary constituents, hydrogen and oxygen. The oxygen is taken up by the iron under the formation of iron oxide, while the hydrogen is liberated. The resulting iron oxide can be reconverted into iron by treating it with reducing gases, to which they will give oxygen under formation of carbon dioxide and steam. The process is therefore reversible.

The iron, theoretically speaking, is not consumed. It serves only as a contact mass, as in its glowing condition it is periodically oxidized with steam and again reduced by being treated with special gases. A gas with reducing action is carbon monoxide or hydrogen itself. Therefore, for the reduction such technical gases can be applied which contain these elements in greater quantities, for instance, generator gas, water gas, or coal gas, etc.

Especially adaptable to reduction is coke gas, as it is composed largely of carbon monoxide and hydrogen. These gases can be produced at very low cost, as the actual material necessary is only coal, coke and steam.

Water gas, for instance, is obtained by passing steam of corresponding temperature through a generating box containing superheated coke. The oxygen of the steam combines with the carbon of the coke, forming carbon monoxide, and the hydrogen is liberated.

FIG. 3—WORKING STAGE ABOVE HYDROGEN GAS GENERATOR PHOTOGRAPH TAKEN BEFORE THE WAR

The following equation explains the reaction:

$$C + H_2O = CO + H_2.$$

The water gas is theoretically a mixture of equal parts of carbon monoxide and hydrogen; practically it contains carbon hydrates and impurities as sulphur combinations, nitrogen and carbon dioxide. For the technical production of water gas, the well known periodically working generators are used. Steam is passed for a while over glowing coke, and the water gas formed is passed through a purifying apparatus into a storage tank. (This is the gas period.)

As the process of forming the gas consumes a great deal of heat, the temperature of the coke is reduced, therefore after about ten minutes the steam supply must be interrupted and air has to be blown through a ventilator into a generator and through stimulated combustion of a part of the coke the required heat is restored. (This is the blow period.)

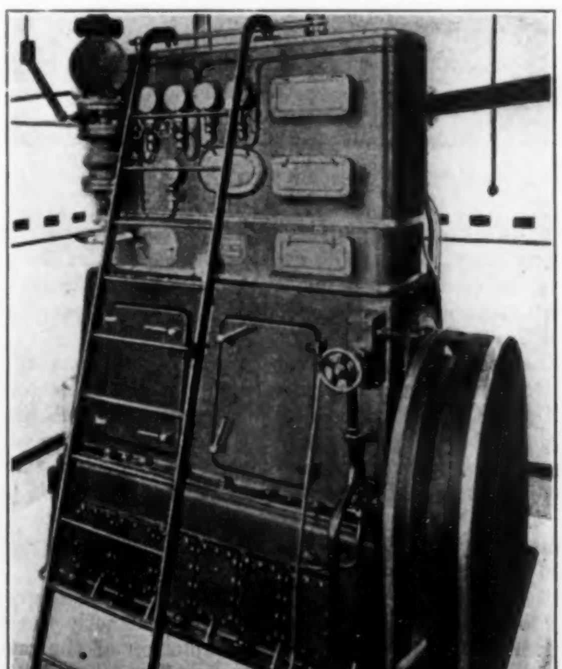


FIG. 5—VERTICAL COMPRESSOR

The products formed by this combustion are removed through a diverting ventilator so that they cannot mix with the gas.

The production of water gas is distinguished by its great simplicity. The generators are extremely reliable to operate, require only limited attention, and can be built for all requirements in units of a generating capacity of 3500 cu. ft. per hour.

The main advantage of the iron contact method is that the only materials required for the production of hydrogen are coke and water, materials easily and cheaply obtained anywhere.

The chemical change in the production of hydrogen by the iron contact method and the application of water gas as reducing agent are explained by the following formulas.

1. Oxidation period:

$$Fe + H_2O = FeO + H_2.$$

2. Regeneration:

$$2FeO + CO + H_2 = 2Fe + CO_2 + H_2O.$$

These two periods are alternating, and each only of such duration as to give chemical reaction in a sufficiently short time. The contact mass must at the same time be kept by heating at such a temperature as is most suitable for the process. This temperature is about 700 deg. to 800 deg. C.

The iron contact method as well as the use of iron or iron ore as contact mass, also the use of water gas or similar gases for reduction of same, are well known.

A number of old extinct patents are existing, and a series of suggestions have been made even lately regarding the practical development of this system, some of which have been partly applied in practice. But many difficulties have been encountered in technical production.

It is extremely difficult to obtain an even degree of heat of the contact mass and regulate exactly the high temperature required for the completion of the process quickly without overheating the mass, which under such conditions would cake together or even melt.

The retort ovens which have been constructed for generating hydrogen are difficult to handle, and proper conditions hard to establish, the contact mass in iron retorts being heated from outside.

Another difficulty encountered in continued generation of hydrogen are the impurities accumulating in the heat and reduction gases. These impurities will form a layer on the surface of the contact mass thereby lowering its progress of reaction by gradual contamination, besides contaminating the produced hydrogen.

In the patented system of Dr. Messerschmitt these difficulties have been overcome. Its fundamental principles are that the hydrogen gas is generated in a generator shaft with separate compartments for heat and contact mass, which are connected in such a way that heating, process of reduction, and generating of gas take place in the interior of one and the same apparatus.

Fig. 6 is a projective reproduction of the three working periods of a hydrogen generator of the Messerschmitt system, explaining the construction of the generator and its working methods.

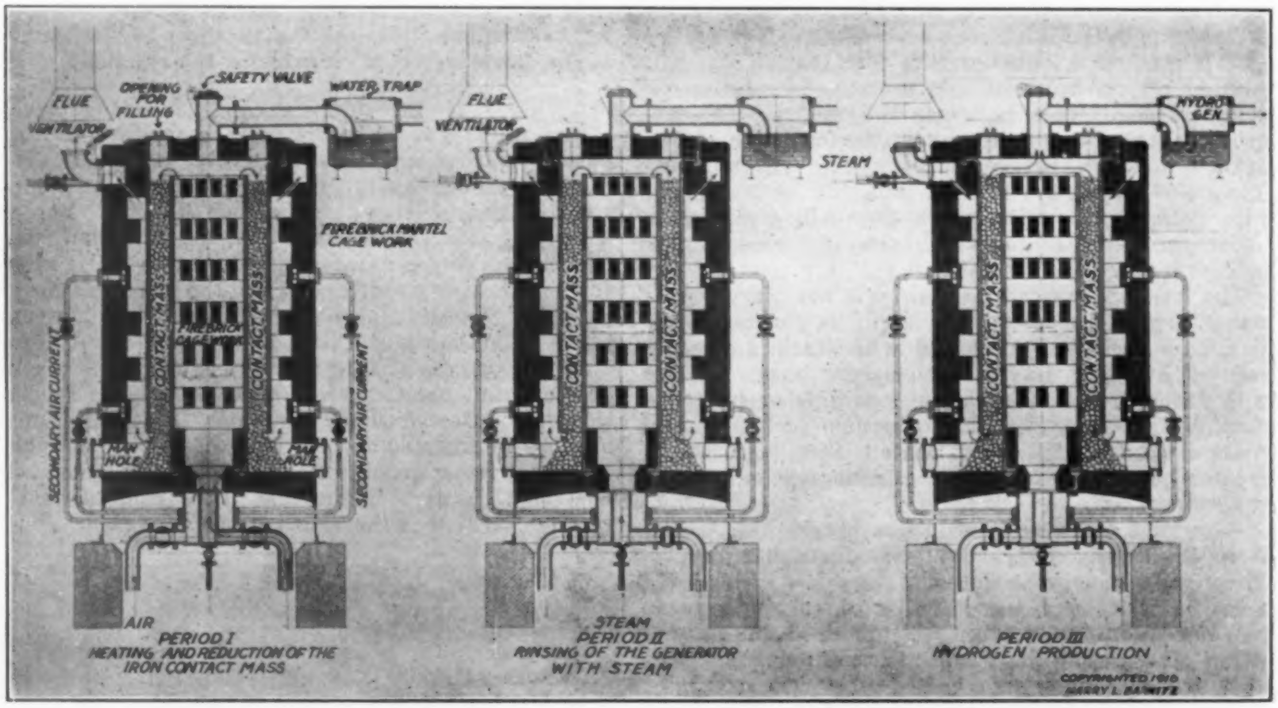


FIG. 6—REPRODUCTION OF THE THREE WORKING PERIODS OF THE LATEST TYPE MESSERSCHMITT HYDROGEN GENERATOR

In a generator shaft, lined with fire brick, two iron cylinders are built in, in a vertical position. The inner cylinder rests on the floor of the generator. Between these cylinders the iron contact mass is stored. In the interior of the inner smaller cylinder there is a cagework of fire brick which serves as storage of heat. The larger cylinder is also surrounded by fire brick cagework which is incorporated in the construction of the outside fire brick mantel of the generator. For the heating of the cagework, and for the heating and reduction of the contact mass, reducing gases and air are introduced from underneath into the interior part of the generator, the air in such volume as not to be sufficient for complete combustion of the heating and reducing gases.

The combustibles and the parts of the gas not consumed rise upwards in the inner cagework, pass through the contact mass downward into the outer cagework where the rest of the gas is consumed by additional or secondary air current, rising again upwards to pass through the flue into the open. The heat is thereby imparted to the cagework, at the same time heating and

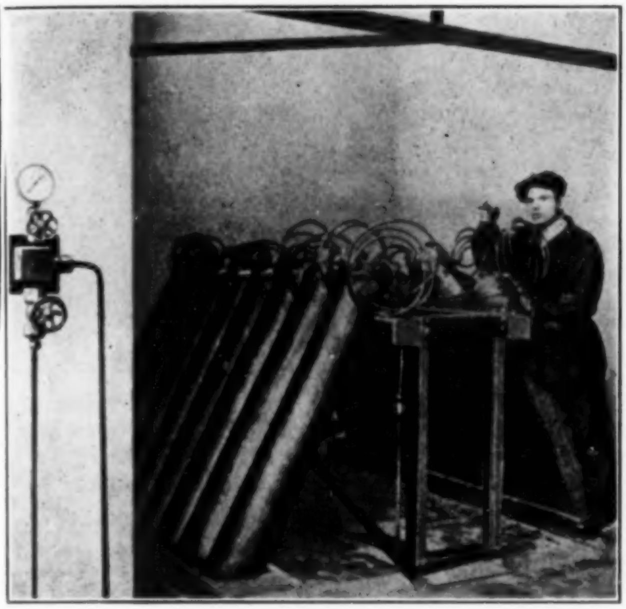


FIG. 7—CYLINDER FILLING

producing the contact mass. The duration of this heating and reduction process is about 20 minutes. After this the supply of heat, reduction gas and air is shut off and steam is introduced from underneath into the generator.

The steam and the carbon dioxide generated from the contact mass are driven out through the flues.

As soon as hydrogen gas escapes with the steam, which can be easily detected by the forming flame, the supply of gas and air is discontinued, and at the same time the ventilator leading to the flue is closed. The so-called rinsing or steaming period now begins which requires only a few seconds; steam being passed through the apparatus as shown in the second diagram.

Then the third period begins. Steam is passed from above into the outer cagework of the generator, and the actual hydrogen production period begins. The steam coming into contact with the glowing contact mass which is now reduced iron is decomposed and hydrogen is liberated with the formation of iron oxide.

FIG. 8—STAND PIPE FOR FILLING AIR SHIPS

The outflow of the generated hydrogen takes place on the top from the middle of the generator into a chamber with a water trap. From there the hydrogen passes through a purifier into the hydrogen gas holder and is then compressed in cylinders or storage tanks. The gas period is of about 15 minutes' duration.

The process is then repeated by again introducing heating and reduction gases and air into the generator. The working method is therefore a periodical one.

The great amount of heat required during the heating and reduction periods is imparted to the contact mass and stored in the fire brick cagework. During the gas period this heat is taken up, the fire brick cagework imparting its heat to the contact mass; besides the introduced steam which passes over the cagework becomes highly superheated and the most effective temperature for reaction is reached. The proper temperature required for this process is between 700 deg. and 800 deg. C., as was mentioned before. This temperature is easily reached in this generator.

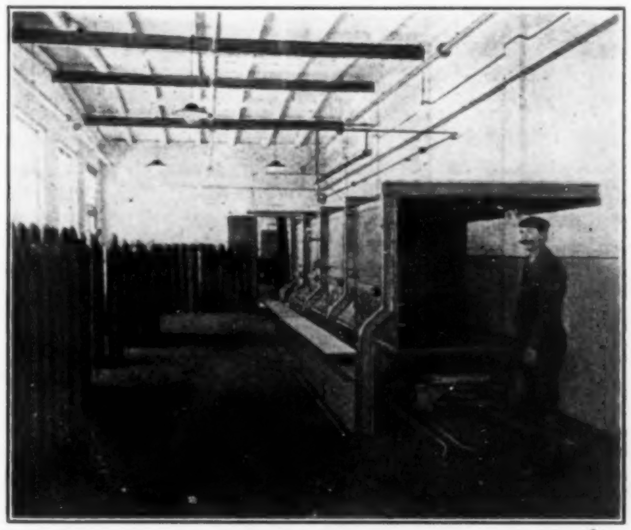


FIG. 9—CYLINDER FILLING WITH PROTECTION CHAMBER AT BORSIGWALDE

Overheating, which would impair the life of the contact mass and the other materials is easily avoided. By the construction of the hydrogen generator of this system an even temperature of the contact mass is obtained without danger of overheating, while the required temperature is quickly imparted.

The total consumption of fuel required for the heating and reduction gases and steam used in the production of hydrogen is very low. The actual cost of the hydrogen gas is governed by the cost of coke and other materials and the size of the installed apparatus. The cost, taken from one plant installed in the United States, averages 40 to 45 cents per 1000 cu. ft. This figure includes interest on investment, depreciation, material and labor.

The generator is very readily put into action, and the heating requires only a few hours.

The arrangement of the heating and contact compartments of this generator exclude all possibility of the hydrogen gas being lost or escaping.

The generator gives off very little heat to its surroundings, the fire brick forming an excellent isolator of heat. The workmen are therefore not troubled by heat or gases. One man can easily attend two hydro-

gen generators—his whole duty is to change levers for each working period and read the pyrometer. All lever positions are automatically locked, thus preventing a wrong position of ventilators.

To replace the contact mass after long use, openings for filling are arranged on the top of the generator, and to remove it, Morton doors are placed on the lower part of the generator mantel.

The heat and reduction gases, as well as the steam, if not available, are produced by the use of a coke generator and steam boiler respectively. One coke generator and one steam boiler are sufficient for several hydrogen generators. The additional requirements for a complete hydrogen gas plant are a few unskilled laborers who can acquire the necessary training in a short time.

The hydrogen produced by this method is nearly chemically pure (99.2 per cent); only traces of nitrogen are present. The purification of the hydrogen gas leaving the generator is done in a simple scrubber in which the dust particles are removed by water. To remove traces of sulphur combinations and carbon dioxide, the gas is passed through a purifier containing iron ore and lime.

Calorizing as Applied to Power Plant Equipment

One of the interesting new things which the research laboratory of the General Electrical Company at Schenectady has developed in the past few years is a process for impregnating iron and steel, with an aluminium alloy known as calorizing. The resulting material is a rich ferro-aluminium of great hardness and possessing heat-resisting qualities much in excess of iron and steel. Calorizing was described in this journal, Vol. XII, p. 730 (Nov., 1914), and Vol. XIII, p. 325 (May, 1915).

One of the interesting new applications of this process is to soot blowers and other power plant equipment. A year ago the Diamond Power Specialty Company, Detroit, Mich., secured sole right as lessee from the General Electric Company to the use of this process in the manufacture of soot blowers and other power plant equipment. The calorized metal is sold in these soot blowers, etc., under the trade name of "insuluminum."

Soon after the calorization process was announced the Diamond Power Specialty Company's engineers instituted an extensive investigation, lasting many months, of the new material. In addition to the mechanical and thermal tests described later, trial installations of soot

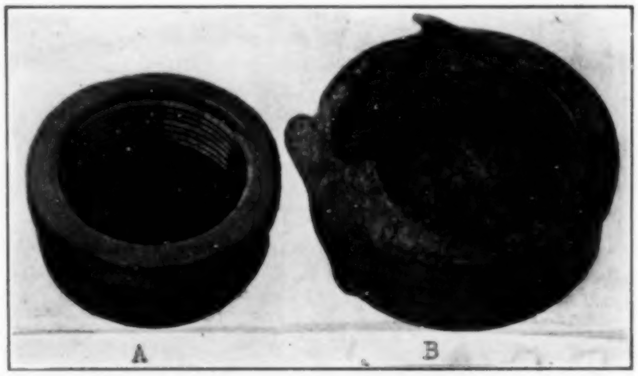


FIG. 1—INSULUMINUM AND EXTRA HEAVY STEEL CAPS AFTER EXPOSURE TO THE COMBUSTION GASES IN THE FURNACE OF A STIRLING BOILER AT A TEMPERATURE OF OVER 2500 DEG. FAHR. A IS INSULUMINUM. B IS "EXTRA HEAVY"

blower units were made in all the different types of water-tube boilers. Units were placed at points in the passes where the temperature ranged from 1800 to 2000 deg. Fahr. The need of blowers at these locations had long been recognized, but their application had been con-

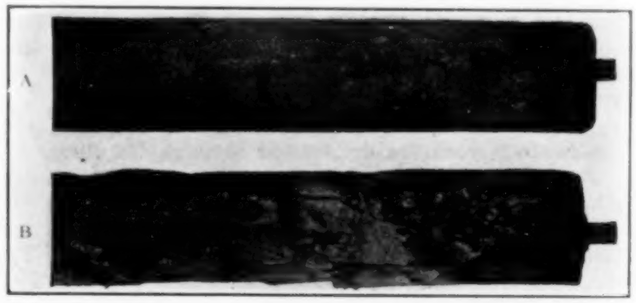


FIG. 2—APPEARANCE OF INSULUMINUM AND PLAIN PIPE AFTER THE SULPHUR DIOXIDE TEST. "A" IS INSULUMINUM. "B" IS PLAIN PIPE

sidered impracticable. In the tests there was no sign of scaling or disintegration from the long exposures to combustion gases at the high temperatures obtaining, and successful installations during the past year have fulfilled all the maker's expectations.

One of the first questions arising in connection with the adoption of calorizing to soot blowers was its ability to withstand the stresses of hard service. The mechanical properties of the new material had to be determined accurately. On this point the General Electric Company stated:

"The coating produced by calorizing is so hard that considerable effort is required to break through it with a file. Consequently, such scratches or scrapings as it receives in normal handling need not be feared at all."

To supplement this information, the Diamond Power Specialty Company conducted a long series of severe tests of insuluminum tubes, subjecting the metal to bending, flattening and hammering processes. The results proved conclusively the homogeneity of the mass, and its ability to withstand severe treatment without failure.

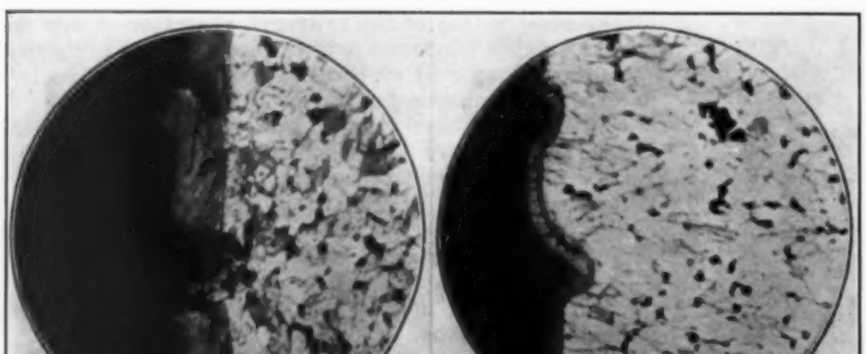


FIG. 3—OUTSIDE BEND AND FIG. 4 INSIDE BEND OF FLATTENING TESTS SHOWING HOMOGENEITY OF MASS AND STRUCTURE AFTER CALORIZING (LIGHT PORTION) MAGNIFIED TO 80 DIAMETERS. MICROPHOTOGRAPHS BY NATIONAL TUBE CO.

The calorized metal will resist for an indefinite time the continued action of temperatures up to 1000 deg. C. (1800 Fahr.). The oxidization of iron and steel becomes pronounced at 500 deg. C., and increases rapidly from this point on.

In Fig. 1 two caps of the type used on soot blowers are shown. These were placed for a short period in a furnace with a temperature of 2500 deg. Fahr., and then plunged into cold water.

The results of a sulphur dioxide test are shown in Fig. 2. Two pieces of pipe, one calorized, the other extra heavy wrought iron, were run side by side in a furnace at 1500 Fahr. in an atmosphere of sulphur dioxide for four hours. At the end of this time the ordinary pipe was so badly decomposed that the experiment was discontinued. The calorized pipe was in as good condition as before the test. In Figs. 3 and 4 are shown microphotographs of the structure of a calorized section after flattening tests.

The calorized metal oxidizes around 1100 deg. C. If the alumina film is broken, scaling will set in at a temperature above 1050 deg. C., but if the film is unbroken the scaling temperature will be higher.

The high heat-resisting quality of the calorized metal makes it much less subject to warping than cast iron or steel.

New Industrial Development Near Pittsburgh

The last stretch of unoccupied river frontage on the Ohio River between Pittsburgh and Wheeling, is about to be opened up, according to an announcement of Ralph W. Cooke, industrial agent, Pennsylvania Lines West of Pittsburgh.

A new line twelve miles in length is to be constructed by the Pittsburgh, Cincinnati, Chicago and St. Louis Railway Company (Pan Handle), commencing at Chester, W. Va., and skirting the south bank of the Ohio River east as far as the mouth of Raccoon Creek, which is about three miles below Beaver.

The Pan Handle now has a branch known as its New Cumberland Branch, from New Cumberland Junction, just east of Steubenville on the main line, north through the thriving industrial towns of Weirton, New Cumberland and Chester, a distance of approximately twenty-three miles and the new line will be a continuation of this branch. The move has been contemplated for some time, as is indicated by the fact that the road has owned the necessary right-of-way for several years.

Construction will be started immediately and it is the intention to have the extension in complete operation some time in the coming year. Ferguson & Edmundson of Pittsburgh have been awarded the contract for the construction of the first portion of the road.

The importance of this development lies in the fact that it will open up extensive acreages of high, level ground, with river frontage suitable for large manufacturing plants. Large tracts of this character, level and at the same time high enough to be free from the possibility of overflow in times of flood, have become exceedingly scarce along the Upper Ohio Valley, a territory remarkable for the industrial development that has taken place in recent years, particularly in the iron and steel industry.

The Steel Corporation has plants at Mingo Junction, Steubenville, Wellsville, Martins Ferry and Bellaire in Ohio and at Chester and Wheeling in West Virginia, all of them along this stretch of river front.

The LaBelle Iron Works has large plants at Steubenville and Wheeling and is now constructing at Follansbee, across the river from their Steubenville plant, a battery of by-product coke ovens.

The Pittsburgh Crucible Steel Company's furnaces and mills at Midland are one of the largest developments in this valley in recent years.

The Phillips Sheet & Tin Plate Company plants at Steubenville, Ohio, and Weirton, W. Va., and the Follansbee Bros. works at Follansbee, W. Va., are continually being enlarged to meet the increasing demand for their products.

The Whitaker-Glessner Company, with plants at Wheeling and Martins Ferry, Ohio, have recently purchased a large acreage at Beech Bottom for open-hearth furnaces, sheet bar mills and ultimately blast furnaces. The Wheeling Steel & Iron Company have made extensive additions to their tin plate department at Yorkville.

In addition to this development of the iron and steel industry should be noted the establishment, about two years ago, of the plant of the Prime Western Spelter Company at Yorkville producing sulphuric acid, and the immense electric generating plant of the American Gas & Electric Company at Beech Bottom, W. Va., with a capacity of 250,000 hp.

There can be no question that the Upper Ohio Valley is susceptible of even more wonderful development in the future.

At Georgetown, at Shippingport and at the mouth of Raccoon Creek are hundreds of acres of ground which are believed to be admirably located and ideal for the construction of large steel mills, chemical plants and other industries requiring large tracts of land and an abundant and never-failing supply of good water.

The whole country back from the river is underlaid with a 6 or 7-ft. vein of Upper Freeport coal, which is not only excellent for steaming purposes, but with the modern by-product ovens will produce a very good grade of coke with the usual by-products, and within a short rail haul are what are known as the Pan Handle District Mines (Pittsburgh seam coal), providing one of the best steaming and gas coals in the world.

There is also considerable clay available which will probably mean the establishment of brick and sewer pipe plants similar to those now existing on both sides of the Ohio River south from East Liverpool and Chester to Steubenville.

The big electric companies will play an important part in the future development of the valley and are making arrangements to extend their lines as fast as the demand for power warrants. In addition to the new plant of the American Gas & Electric Company mentioned above, the Duquesne Light Company and the West Penn Power Company are enlarging their power plant facilities and adding miles of new high tension lines. It is stated that electric current can be produced and sold in the Upper Ohio Valley "as cheaply as at any other location in the country."

Personal

Mr. **H. Reeve Angel**, of Messrs. H. Reeve Angel & Co., London, England, representing Messrs. W. & R. Balston, manufacturers of the well-known Whatman filter paper, was an interested visitor at the National Exposition of Chemical Industries.

Mr. **George A. Burrell**, formerly in charge of research work in gas and related investigations for the Bureau of Mines, Pittsburgh, Pa., has resigned his position to enter consulting work. Mr. Burrell has been with the Bureau of Mines for twelve years and is well known for his work and publications on mine gases, natural gases, gasoline, acetylene and illuminating gas.

Mr. **E. J. Cornish**, formerly vice-president, has succeeded the late W. W. Lawrence as president of the National Lead Company.

Mr. **H. R. Hanley**, formerly general manager of the

Bully Hill Company, has been appointed superintendent of the Mammoth Company's new $350,000 electrolytic zinc plant that is to be erected near the Mammoth smelter in California.

Mr. **O. C. Ralston**, assistant metallurgist of the U. S. Bureau of Mines, with headquarters at Salt Lake City, is now making an extended trip through the Southwest for the purpose of gathering information in regard to the low-grade and complex lead and zinc ores of that part of the country.

Mr. **J. W. H. Randall** has resigned his position with the Curtis Bay Chemical Company, and has become associated with the West Virginia Pulp & Paper Co., at its Piedmont plant.

Dr. **Walter F. Rittman** was recently in Texas in the interests of his oil-cracking process.

Mr. **I. Schoenawa**, formerly of Siemens & Halske and joint author of a book on electric steel furnaces, has been appointed managing director of the Charleston Steel Company, Charleston, W. Va.

Several changes and appointments in the chemistry department of the University of Illinois have recently been made. Professor **Richard C. Tolman**, recently at the University of California, has been appointed professor of physical chemistry to succeed Professor **E. W. Washburn**, who has been appointed head of the department of ceramics. Dr. **Roger C. Adams** has been appointed assistant professor of organic chemistry to succeed Dr. **C. G. Derick**, who is organizing a research laboratory for the Schoellkopf Aniline and Chemical Works in Buffalo. Dr. **Horace G. Deming**, recently returned from the Philippines, has been appointed associate in chemistry to assist in the instruction in general chemistry and qualitative analysis. Professor **C. W. Balke**, formerly at the head of the division of general chemistry and qualitative analysis, is organizing a research laboratory for the Pfanstiehl Company in North Chicago which is engaged in the application of rare metals to industrial uses.

Industrial Notes

Counter-Current Decantation for Chemical Industries.—The Dorr Company, Denver, Col., has issued a new catalog, No. 8, dealing with continuous counter-current decantation for chemical industries. The use of the Dorr apparatus is well known to metallurgists, but it was with the idea of acquainting chemical engineers and those connected with chemical industries with the possibilities of this apparatus that the catalog was prepared. On account of the confidential nature of all work in connection with the chemical industries, it was impossible to publish many data concerning the operation of Dorr equipment in such plants. A number of flow sheets are, however, given with the company names omitted. Among the interesting applications are the manufacture of caustic soda from soda ash and lime, alum from bauxite and sulphuric acid, borax from colemanite, barium carbonate from barium sulphide and soda ash, extraction of iron stains from barytes, and phosphoric acid from rock phosphate.

The **Tivani Steel Company**, Belleville, Ont., Canada, which has been experimenting for some time on an electric smelting process for the direct reduction of refractory ores, is now about to engage on a commercial scale in the manufacture of high-speed molybdenum steel. A three-phase electric furnace is used.

Electrolytic Zinc.—Preliminary work on the new electrolytic zinc plant of the Mammoth Copper Co., was started a short time ago at Kenneth, Cal. The plant will be erected on Big Blackbone Creek, above the Mammoth smelter and will cost about $350,000.

Corrosiron.—The Pacific Foundry Company, San Francisco, has issued a catalog describing its product, corrosiron, an acid-resisting machineable iron. It is a high-silicon alloy made by a specially developed process for resistance to corrosion of acid and alkali solutions.

Flotation Oils.—The General Naval Stores Co., New York City, has prepared a booklet describing the flotation oils which it supplies. The primary object in writing this booklet was to get together specific information on flotation oils of a kind which would be most useful to the man in the mill, rather than addressing it to metallurgists who have had special training in this field. An outline is made of the "frothing" and "foaming" properties of various kinds of oils, with suggestions for combining them to produce the proper combination of physical properties to successfully treat a given ore. This booklet sums up the company's observations on oils as applied to flotation, both through letters from operating companies and investigators, whose comments have been invited, and from observations in actual large scale tests conducted at mills in the West.

Fellowship for Asphaltic Research.—With the cooperation of Harvard University and the Massachusetts Institute of Technology, the Barber Asphalt Paving Company has established at these institutions a fellowship for research in asphaltic materials and their uses. The fellowship is to be known as "The Clifford Richardson Fellowship." Mr. Richardson is a distinguished alumnus of Harvard and this, taken in connection with his great contributions to asphaltic highway construction and his work in the chemistry of bitumens, makes the designation of the fellowship particularly appropriate. The appointment of the incumbent of the fellowship and the choice of subjects for investigation, as well as the disposition to be made of the results of such investigations as may be undertaken, are to be decided by the Institute faculty or the joint committees of the University and the Institute having control of engineering work.

New Officers of Institute of Metals.—The officers elected for the coming year at the annual meeting of the American Institute of Metals in Cleveland are as follows: President, Jessie L. Jones, Westinghouse Electric & Mfg. Company., Pittsburgh, Pa.; secretary, W. M. Corse, Titanium Alloy Mfg. Company, Buffalo, N. Y.; senior vice-president, George C. Stone, New Jersey Zinc Company, New York; vice-presidents, R. S. B. Wallace, National Cash Register Company, Dayton, Ohio; William B. Price, Scovill Manufacturing Company, Waterbury, Conn.; George K. Burgess, Bureau of Standards, Washington, D. C.; deCourcy Browne, Goldschmidt Thermit Company, New York City; Harold J. Roast, the James Robertson Co., Ltd., Montreal, Que.; J. P. Salter, Ohio Brass Company, Mansfield, Ohio; F. H. Schutz, H. Mueller Manufacturing Company, Decatur, Ill.; W. A. Cowan, National Lead Company, New York; H. S. Gulick, More-Jones Brass & Metal Company, St. Louis, Mo.

Leather Investigations.—The Council of the American Leather Chemists Association has outlined the following work which will be subjects for committee investigation during the winter 1916-17: Analysis of Tannery Effluent; Dye Testing of Leather with Artificial and Natural Dye Stuffs; Solubility of Hide Substance in Sodium Chloride Solutions; Effect of Alkali on the Soaking of Dry Hides; Determination of the Ash Tanning Materials and Leather; Disinfection of Hides; Analysis of Sulfonated Oils; Comparative Analysis of Tanning Materials by the A. L. C. A.; Official Methods; Effect of Hard Waters on Tannin; Determination of Free Sulfuric Acid in Leather.